Proposed Rosemont Copper Project

Resolution Meeting for Groundwater Modeling Issues
October 18, 2012

Attendees:

<table>
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<tr>
<th>Forest Service</th>
<th>Forest Subcontractors</th>
<th>Other</th>
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<tr>
<td>Jim Upchurch</td>
<td>Chris Garrett (SWCA)</td>
<td>John Hoffman (USGS)</td>
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<td>Jamie Kingsbury</td>
<td>Melissa Polm (SWCA)</td>
<td>Stan Leake (USGS)</td>
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<td>Salek Shafiqullah</td>
<td>Dale Ortman</td>
<td>Jean Calhoun (USFWS)</td>
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<td>Roger Congdon</td>
<td>Terry Chute (facilitator)</td>
<td>Jason Douglas (USFWS)</td>
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<td>Mindee Roth</td>
<td>Vladimir Ugorets (SRK)</td>
<td>Dan Moore (BLM)</td>
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<td>Larry Cope (SRK)</td>
<td>Carter Jessup (USEPA, by telephone)</td>
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<td>Cori Hoag (SRK)</td>
<td>Hale Barter (Montgomery &amp; Associates)</td>
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<td>John Whittier (Montgomery &amp; Associates)</td>
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<td>Mark Cross (Montgomery &amp; Associates)</td>
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<td>Grady O’Brien (Hydro-Logic)</td>
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<td>Kathy Arnold (Rosemont Copper)</td>
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Topics Discussed:

- Discussion of concerns over validity of boundary conditions if stress reaches boundaries, need for reformulation of boundaries, preference of boundaries based on real features, and desirability of steady-state solution (Congdon, Leake)
- Discussion of concerns that problems with boundary will affect timing of impacts, which would change overall assessment (Calhoun)
- Discussion of concerns that the mine is simply too close to the western boundary, and concerns that any impacts beyond boundary cannot be known (Shafiqullah)
- Presentation of history of boundary selection (Barter, O’Brien)
- Presentation of new constant-flux sensitivity analyses (Barter, O’Brien)
- Discussion of applicability of model to distant water sources
- Discussion of applicability of a steady-state model
- Overview of current riparian analysis (Garrett)
Decisions Made:
• Jim Upchurch asked for concurrence on using the existing models, and received it from Salek Shaffiqullah, Roger Congdon, and Stan Leake, albeit with some reservations requiring disclosure in the EIS.

Action Items/Assignments:
• A robust discussion about boundary conditions will be incorporated into the EIS. A steady-state model will not be run, but the ultimate effects of the steady-state will be discussed.
• Rosemont groundwater modelers to compile recent documentation on the boundary conditions; Forest will submit a request letter for this documentation.
Attachments:

1. Meeting Agenda
2. Meeting Transcript
3. Results of constant flux sensitivity analyses provided prior to meeting by Montgomery & Associates
4. Results of constant flux sensitivity analyses provided prior to meeting by Hydro-Logic
5. “A New Capture Fraction Method to Map How Pumpage Affects Surface Water Flow.” Publication provided by Stan Leake prior to meeting.
6. “Problems with the Rosemont models.” Position paper provided by Roger Congdon prior to meeting.
Agenda

Rosemont Copper Project
Resolution of Groundwater Modeling Issues
Thursday, October 18, 2012, 10:00 AM
Lodge on the Desert, Catalina Room, 306 N. Alvernon Way, Tucson
Conference phone line: 866-740-1260, passcode 5410791#

Invitees:

Forest Service (Jim Upchurch, Jamie Kingsbury, Roger Congdon, Mindee Roth, Salek Shafiqullah); BLM (Dan Moore); EPA (Carter Jessup); USGS (Stan Leake, John Hoffman); USFWS (Jason Douglas); SWCA (Chris Garrett, Melissa Polm, Jonathan Rigg, Dale Ortman, Terry Chute [Facilitator]); SRK (Cori Hoag, Vladimir Ugorets, Larry Cope); Montgomery & Associates (Hale Barter); Engineering Analytics (Grady O’Brien); Rosemont (Kathy Arnold)

Purpose of Meeting:

The groundwater modeling process for the Rosemont Copper Project has been underway since 2009. The process was meant to be inclusive and defensible, and has involved consultants for Rosemont, Forest specialists at the local and national level, specialists from cooperating federal agencies, and peer review by third-party Forest Service contractors. Many modeling issues have been resolved to the satisfaction of the Forest Service as a result of this process.

However, as the NEPA process continues towards completion, Forest Service and other federal specialists have indicated that several concerns remain with the groundwater models. The Forest Supervisor has requested that these final concerns be resolved. The purpose of this meeting is to resolve the issues to the satisfaction of the Forest Service by bringing all involved specialists together, preferably in person, to articulate the remaining concerns with the groundwater models, examine all available evidence, and either resolve the issues in the meeting or determine specific steps that are necessary to resolve the outstanding issues.

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<tr>
<th>Time</th>
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<tr>
<td>10:00-10:15</td>
<td>Introductions, Ground Rules, Housekeeping</td>
<td>Terry Chute</td>
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<td>10:15-10:30</td>
<td>Introductory Remarks, Goals of Meeting</td>
<td>Jim Upchurch</td>
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<td>10:30-10:40</td>
<td>Meeting Structure</td>
<td>Terry Chute</td>
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<td>10:40-10:45</td>
<td>Reminder of Consultant Roles</td>
<td>Chris Garrett</td>
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<td>10:45-11:45</td>
<td>Identification of Remaining Concerns</td>
<td>Roger Congdon, Stan Leake</td>
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<td>11:45-12:45</td>
<td>Presentation of Recent Modeling Work</td>
<td>Grady O’Brien, Hale Barter</td>
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<td>12:45-1:45</td>
<td>Break for Lunch</td>
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<td>1:45-4:30</td>
<td>Reconvene; Open Discussion</td>
<td>All</td>
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<td>4:30-5:00</td>
<td>Summary of discussion; questions from the audience; closing remarks</td>
<td>Open</td>
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ATTACHMENT 2

MEETING TRANSCRIPT
GROUNDWATER MODELING ISSUES

October 18, 2012

Tucson, Arizona
ATTENDEES:

USFS: Jim Upchurch
Roger Congdon
Salek Shafiqullah
Mindee Roth
Jamie Kingsbury

SRK CONSULTING: Vladimir Ugorets, Ph.D.
Larry Cope, Senior Consultant
Corolla (Cori) Hoag, P.G., C.P.G.

USGS: Stan Leake
John Hoffman

BLM: Dan Moore

EPA: Carter Jessop, via telephone

SWCA: Terry Chute, Facilitator
Chris Garrett
Dale Ortman
Melissa Polm

USFWS: Jean Calhoun
Jason Douglas

MONTGOMERY & ASSOCIATES: Mark Cross
Hale Barter
Jon Whittier

ENGINEERING ANALYTICS: Grady O'Brien

ROSEMONT COPPER: Kathy Arnold
TERRY: Good morning, everybody; glad you could make it this morning for the groundwater modeling meeting. My name is Terry Chute. I'm a consultant with SWAC. We do NEPA consulting and facilitation and other chores as assigned and I'll be facilitating today's meeting.

So you all have an agenda in front of you. We have a lot of stuff to cover in a relatively short amount of time today so we're going to get right after it.

What I would like to do is just go around and do introductions and if you'd just say what your name is and who you're with -- I think many of the people in here know each other, some of us don't, and we have folks on the phone so, Stan let's start with you.


JOHN: I'm John Hoffman, also with the USGS here in Tucson.

CHRIS: Chris Garrett with SWCA.

JEAN: Jean Calhoun with Fish and Wildlife Service.

LARRY: Larry Cope with SRK.

DAN: Dan Moore, Bureau of Land Management.
JIM: Jim Upchurch, forest supervisor with Coronado.

VLADIMIR: Vladimir Ugorets, SRK Consulting.

SALEK: Salek Shafiquallah, hydrologist with the Coronado National Forest.

CORI: Cori Hoag, SRK Consulting in Tucson.

GRADY: Grady O'Brien, and just recently went out on my own so now I'm hydrologic. Instead of Engineering Analytics I will be talking about the Tetra Tech model.

HALE: I'm Hale Barter with Montgomery & Associates playing the same role as Grady. We're talking about the Montgomery & Associates' model and some of the investigation that led up to the model implementation.

TERRY: Dale?

DALE: Dale Ortman, consultant with SWCA.

JAMIE: Jamie Kingsbury, Acting Deputy Forest Supervisor, Coronado National Forest.

KATHY: I'm Kathy Arnold with Rosemont Copper.

MINDEE: Mindee Roth, project manager
with the Forest Service.

MELISSA: And I'm Melissa Polm with SWCA.

TERRY: And we have a court reporter up here taking notes today so we have a good transcript of it.

And your name is?

REPORTER: Cindy Shearman.

TERRY: I should remember that because Cindy and I also worked together at some of the public meetings earlier.

I'd like to go over the agenda really quickly just so everybody knows what's on it. And add a couple of notes.

So I have --

MINDEE: Terry, do we have people on the phone?

TERRY: Oh, thank you for reminding me of that.

Is there anybody on the phone right now?

Apparently not. We're expecting somebody from EPA to call in, Carter Jessop, and Bev from the Forest Service at some point today. So we'll keep track of that and if I hear that come in, we'll stop and make sure they introduce themselves.
Thank you, Mindee, I appreciate that.

So I'm going to go over the agenda ground rules and housekeeping.

Then we're going to ask Jim to kind of set the stage for us -- Jim Upchurch to kind of set the stage for us, talking about the purpose and expectations for the meeting. And we are going to attempt to capture the salient points on a flip chart.

I'll come back in and talk for a few minutes about the structure of today's meeting and how we anticipate this flowing.

Chris will talk for a few minutes about a reminder of the role of the various consultants that are involved in the project, all or most of which are sitting in the room today.

Then we're going to jump in. And, by the way, Roger Congdon with the Forest Service is on his way from the airport as we speak. So we're expecting Roger to be here shortly. Then we'll jump into having Roger and Stan Leake and Salek describe the Forest Service's concern, remaining concern with water modeling, and we are also going to try to capture the salient points from that discussion on a flip chart.

Have Grady and Hale do a presentation on their recent modeling work.
We'll break for lunch and reconvene and then the rest of the day will be spent in open discussion and we'll leave some time at the end for closing statements from Jim.

So that's generally how we're going to flow today.

Probably don't need to go over a lot of ground rules but for the sake of just having them on the wall, we want to please have -- make sure everybody has their phones either turned off or set to buzz. Want to keep it respectful today. Have one person speaking at a time. Please no criticism of one another. Focus on interests and the problems at hand and not positions. Keep the discussion focused on the -- what we're here to achieve today. Be on time when we're coming back from lunch and breaks. And listen actively; try to hold side conversations off for breaks and lunch.

So, with that, a little housekeeping. The bathrooms are directly behind this fireplace. To get to them you need to go out this door and around the corner. We probably will not have a break this morning since we're getting started at 10:00. If we go longer before lunch, we'll work a break in, and then I'll work a break in this afternoon, even though it's not on the agenda.
So any questions on those things? Questions, comments?

GRADY: Do you have wi-fi in here, by any chance?

TERRY: Yes, we will get the code. We need to get that from the hotel. Thanks.

So, with that, I'd like to turn it over to Jim to kind of set the stage of today's meeting.

JIM: Thanks, Terry, and thanks, Mel, for getting this set up and thanks to all of you for coming to this gathering here of distinguished scientists and folks that are specialists in water quality and water quantity and groundwater geology.

So why are we here today? I guess that's one of the questions I should answer. You all met earlier back in May. Unfortunately, I couldn't be there for that last meeting that you had. But I did read the transcripts and I read the notes and the briefing papers and so I know what was discussed. And I know, you know, what the issues that you were talking about are.

But, you know, we still have issues related to groundwater geology, groundwater issues related to how that might affect the Outstanding Arizona Waters, Upper Cienega Creek, and the Cienega National Conservation
Area. So those are important issues that I still need to address as the decisionmaker for this particular project, the Rosemont Copper Mine.

So subsequent to that meeting that you guys had, we were able to take a lot of that information and from our specialists, we asked Rosemont to provide additional information to us to help resolve some of the groundwater issues, concerns about models, and we did get response from Rosemont on that, the consultants, I think right around July 1st, somewhere around there.

And so our specialists, our folks, have been looking at that information and trying to determine if it answers the questions that were raised. And so they've been meeting with me and so from what I've been hearing from our folks, that there's still some concern over the applicability of the groundwater models. And although many of the issues that were raised have been resolved or better verified, there's still some outstanding issues.

Some things have been addressed and some things have been changed with Rosemont's proposal. They've eliminated the heap leach proposal for treatment of oxide ore within the throes of the proposed alternative. They've improved the storm water
drainage pattern that would come off the tailings and 

waste rock and have done geomorphology designed to help 

alleviate some of the seepage issues and other things 

that were an issue before. 

So a lot of work has been done to try to 

resolve some of those outstanding issues and that has 

done a lot to increase water downstream, which I think 

was one of the issues raised, was how much surface 

water would be going downstream. So that's helped a 

lot. 

But there's still that nagging issue of that 

western boundary on the groundwater model and that, you 

know, when I keep hearing about those issues, I've got 

to try to figure out how to resolve them. 

So, as the decisionmaker, it's my 

responsibility to disclose the facts, to take a hard 

look at the analysis, and to use the best available 

science in that analysis to make a reasoned and 

informed decision. 

And so, to do that, I have to make sure I've 

got the best science, and that's one of the reasons why 

you all are here is to help me in that NEPA requirement 

of using best science and to come to some -- some point 

where I can make a reasoned decision. 

I've had many specialists and scientists
coming at this issue from different opinions. And I can document those differences in the EIS and just say that we have differences or I can try to resolve them. But this particular issue is of such significant effect on the resources downstream that I didn't want to just say: Well, we have differences and this is the way we're going to go.

But I wanted to be able to hear firsthand from all of you so that I can better understand where there are differences and where there might be places to get resolution. So that's one of the main reasons why we're here is that I need to be able to better understand if there are issues, if there are ways that we can resolve them, if there are ways that we can come to a point where we're all looking at the end result, which is the big picture is that are the effects going to have a significant effect on downstream resources.

Models, you know, I'm going to hear about models today, and models are just that: they're a predictor. But they -- they predict a certain thing. But I need to know is -- what I need to know is are they going to have a significant effect, the project itself, is it going to have a significant effect on downstream resources that we're concerned about.

So I want you to keep the big picture in mind,
too, not just the technical pieces, but with all this information, is it going to make a difference if we go one way or another. And that would help me, too, to know, you know, if we go one direction versus another direction, does it really make any difference in the big picture.

So understanding the differences, looking to resolution, and, you know, just asking for your assistance in keeping a look at the big picture will be helpful to me as we go forward in this process, and so, you know, that's the reason from my standpoint why we're here -- why we are here.

If you thought we were here for a different reason, then I'm sorry. But it's really all about me today and trying to help me to understand where we're going to go with this decision.

So is there any questions or any thoughts about that?

GRADY: You're talking about the big picture. Why don't you tell us a little bit from your perspective what that big picture is, a little more detail there?

JIM: Well, when I think about the big picture, I'm thinking about are we going to have effects so significant to a particular resource, like
Arizona Outstanding Waters or to the National Conservation Area, that would be of -- I'm using this term "significance", but would be of such significance that I need to either go back and try to see if we need to amend or resolve or try to change the current effects on those resources, or they're not of such significance that we can go forward with a decision.

So when I say the big picture, it's just trying to keep in mind that it's really about that, the effects on the Arizona Outstanding Waters and the National Conservation Area, not necessarily whether, you know, a particular reach is going to be affected by .001 inches or something like that. It's that big picture of we have a -- some regulatory -- regulatory needs for Arizona Outstanding Waters as well as trying to meet the concerns with the Conservation Area. So when I say big picture, that's what I'm talking about, Grady.

TERRY: Any other questions for Jim? So we've had two folks come in since we've started the meeting. Would you please, starting back with Jason, just say your name and who you're with.


MARK: And Mark Cross, President of
Montgomery & Associates.

TERRY: Okay. Thank you. Do we have anybody on the phone yet? Apparently not.

So, as we go through today, because we do expect folks on the phone, when you speak, if you would say your name first so that people on the phone, assuming somebody gets on the phone, will know who's speaking, we would appreciate that.

So the meeting structure today is somewhat different than the groundwater meetings we've held to date. You know, as Jim said, it's kind of my interpretation of, in talking with Jim to help get ready for this meeting is, you know, there's been a lot of work on a whole wide variety of issues on groundwater and groundwater modeling and predicting impacts, and it's boiled down now to fewer issues that the Forest Service still has concerns about. And so we're here today to resolve, to the degree we can, those issues or concerns.

So in talking with Jim and, Jim, I want to bounce this off of you and tell me if this is a correct expectation, that we are hoping to either resolve these issues in today's meeting or plot a clear course for resolving them.

JIM: That's right. If we don't come
out of here without either resolution or a path forward, then I don't think we've been successful. So that's the expectation.

TERRY: So the way we set this meeting up today was the folks around the table here are the responsible officials for the Forest Service, Jim, and the folks with the Forest Service, like Salek and Roger, that have expertise and responsibility for groundwater analysis, and the various folks with SWCA and the consultants that have been involved with modeling and some of our federal partners, like Fish and Wildlife Service and BLM.

We are going to try to keep the conversation today on the issues at hand and keep that confined primarily to this table. The folks in the back have been involved with this in various capacities but for today's discussion we're going to ask you to kind of hold off on participating. If we have time this afternoon at the tail end of today, we will bring you in and ask you if you have questions or comments as time allows. So that's kind of how today is set up.

The other thing I would like to stress today is kind of three things that come to my mind that I think need to focus our efforts. I think we need to be positive in our discussion, we need to be proactive in
resolving these issues, and we need to have a
problem-solving approach. So I think Mel's going to
write those down and put those up on the wall and I'm
going to use those to help focus the discussion today,
and if we get outside of the bounds of solving the
problem, I'm probably going to try to rein you back in
because that's why we're here, okay? Questions of how
today's going to go?

So, with that, we'll turn it over to Chris.

CHRIS: So this will take all of two
minutes and that's my piece. This seemed to be pretty
handy last time we met to go over the different
consultants that are sitting around the room and kind
of where they fit into this whole process. There's
kind of three categories, only two of which are present
here. There are consultants that are -- there are
consultants here that are hired and contracted to
Rosemont, mostly today that's Montgomery & Associates
and that's Hale and Mark, and then Grady is here.

Now, the original model was done by Tetra
Tech, the one that Grady's responsible for. It was
done by Tetra Tech then Grady moved to Engineering
Analytics and now apparently that's out of date, too,
so just know that Grady is in charge of the second
model. We call it the Tetra Tech model, but that's
Grady's baby here.

AMEC isn't involved today at all but they did some of the infiltration analysis so that's why they were on this list.

There are also consultants that are contracted to the Forest and work at the direction of the Forest, SWCA being the NEPA consultant; SRK, and we've got three SRK people sitting at the table here: Larry and Vladimir and Cori. They have largely been in charge of peer review on the modeling, and that includes all of the geochemical and infiltration modeling as well, but we only brought the people who are kind of the groundwater people today.

MWH is not present. They were in charge of doing peer review on the westside model.

Golder & Associates, they were here at the last meeting but they also are not here today. They don't really have a role in this groundwater portion.

And then there's other consultants involved in the whole groundwater mix. Honestly, last time the Myers' model did not come up, but Dr. Tom Myers was contracted by Pima County to produce a third model, which we also used in the EIS.

So I think that covers all the people that are in the room working for consultants. But I just wanted
to point out who's contracted to whom and what their role is. So that's it.

CARTER: Sure, yeah. You're doing introductions. I know you're doing consultants but I'm with USEPA, this is Carter Jessop. I don't have any particular groundwater expertise but I'm sort of on just listening.

TERRY: Thanks, Carter. My name's Terry and I'm going to be facilitating today's meeting. So we will try to say our names when people are speaking today. If we forget or if I forget that you're on the phone, please break in and remind us.

CARTER: Okay, thank you.

TERRY: So, Roger got here.

Hi, Roger. Terry Chute here. So could you introduce yourself and just say who you're with?

ROGER: Roger Congdon. I'm the hydrogeologist for the Forest Service, Washington office, stationed in Albuquerque.

TERRY: Okay. So we started about 20 minutes ago, and we are -- so we're at the point now we're well ahead of schedule, which is a good thing to give more time for discussion. So we're to the point now where Roger and Stan and Salek, we're going to ask them to describe the remaining concerns with
groundwater modeling and we're going to try to capture the salient points on a flip chart, so you may have to help us get those salient points written.

    JIM: And, Roger, we have EPA on the phone so you might have to describe if you've got something showing on the screen.

    ROGER: Well, I have words that appear to be sitting on a lake of ice.

    Boundaries, do they matter? I was kind of raised into hydrology, hydrogeology to believe that they did. And I was mentored by people such as Mike McDonald whom I got to be associated with in a project in the past. And, you know, especially considering that all these things are based on partial differential equations and way back in the Miocene when I was taking that in college, they taught us that, well, yeah, you can solve these problems but basically you have to keep them from blowing up in certain places or being inappropriate in others.

    So you pin them down with boundary conditions, which are sometimes artificial and sometimes have some meaning, and they definitely do matter. And the difference between artificial and natural boundaries, quote, unquote, is that the natural boundaries are things like evapotranspiration and interaction with
rivers, and artificial boundaries are those that we use to keep the model from getting maybe too big. So we put them on the edges to fix the water table or to fix the water table at some distance beyond the edge instead of using something like hydrographic boundary basins.

So -- next slide. So a comment was made by somebody along the line, and I don't recall who, that they did not know of any ASTM standard. I absolutely hate slides with words on them but this one seemed to be particularly appropriate coming from ASTM Standard Guide D5609-94 defining boundary conditions in groundwater flow modeling.

And in 6.4.1 the section says: A specified head boundary assumes the head is independent of the stress in the model. If the stress applied to the real system will affect the head on the boundary, the boundary is stress-dependent and modeling the boundary as a specified head boundary is not a valid representation of the boundary.

Okay. And it also goes on to say in 6.4.1.2: If the boundary conditions are stress-dependent, the model cannot be considered a general all-purpose tool for investigating any stress on the system because it will give valid results only when the stresses do not
impact the boundary. The study of a new stress on the same model may require the reformulation of the representation of boundaries of the model and sensitivity tests on the model boundary representation.

And I feel that this is significant because obviously when we start modeling a system, a mining project, what have you, we may have to revisit the model. We may find out conductivities were too low. We may find out there's a fracture zone that is particularly transmissive. And then we may have to go back to square one.

Okay. In just a couple of projects I was involved with up in northeast Nevada, which ones -- well, actually, I shouldn't have named it because which ones they are is not really important. But this one was made for the mine, as you can see in the cross hairs of the fine discretization in the middle, was an open pit mine.

It was shown they have general head boundaries on the western edge and you can see in their little dots along the western edge and along the south boundary -- it doesn't really show it -- I believe that Humboldt River cells on the far south were considered constant head on the first layer of the model.

Okay. And what we got was the predicted
maximum extent of the ten-foot drawdown contour and 
basically what you see there is that the maximum extent 
does not approach very closely except perhaps in the 
north to the outer model boundaries.

And, as in the model we were looking at 
earlier, there was -- for this project, there was some 
artifacts on the Tucson area that there was some 
concern and this model also had some artifacts that 
were on the east side. And you can see a drawdrown 
zone there that's related to the model but probably not 
to the simulated pumping. We didn't try to explain 
that.

And this is a project that Vladimir may have 
some familiarity with, but this was basically the same 
area, same six-basin area, and you can see there's six 
hydrographic basins, if you can see those dark lines on 
there, and a cone of depression that extends towards 
the boundaries. But, once again, does not impinge upon 
the boundaries.

And there was that little blurb at the bottom 
in the report from the -- that said: All boundaries 
with the exception of the southern boundary along the 
Humboldt River are considered flow boundaries in steady 
state simulations. The Humboldt River is simulated 
using specified heads. Transient simulations, all
nodes along the Humboldt River except for nodes in the uppermost layer converted to a variable flux boundary. This allows flow into and out of the model domain beneath the Humboldt River. Similarly, all no-flow boundaries are converted to specified flux boundaries.

Okay. But basically the point is that the project pumping in all cases except for one small part at the south boundary did not impinge upon the boundaries.

Was there a question?

Okay. And then just basically if we look at steady state modeling, which is of interest, there is no time factor and, I mean, we make a big deal about, well, we model this out to 1,000 years or 2,000 years or 10,000 years and basically at steady state we don't worry about that. We don't worry about storage coefficient specific yield because they're irrelevant. And boundary flux at steady state is -- everything is in perfect harmony, which is the ideal position we'd really like to say. Whether we can do that remains to be seen but I see it as a goal that we should really try to work toward.

And those are just my major points. Once again, I just got back from Atlanta and I only had a few minutes to throw this together but if you have any
questions, please ask and I'll either deflect them to Stan or attempt to answer them myself.

TERRY: And if you would on this, I was going to say this to begin with, but I forgot, but at this point I'd like to keep those questions to clarifying questions at this point and not get into debate at this point.

ROGER: Okay. Any clarifying questions at this point?

SALEK: So, Roger, on your example, did they try something different or did -- was the final result what you're showing us or was there they tried something different earlier and it didn't work and that's what they settled on?

ROGER: Well, interestingly enough, they did.

SALEK: What was the example?

ROGER: It was an interactive process, with the BLM being a pain in the rear and the mines doing what they were doing, and in the case of that first model, that was actually the third cut. In fact, not even the third cut, it was the third consultant.

The second model was a square box model with mostly artificial boundaries done by a consultant I shall not name but is well known to most of us around
here. And we attacked them on certain boundary issues and they ended up firing this consultant and hiring another, but we ended up with a beautiful model.

SALEK: So it went through iterations. And so at the end, when they actually developed the mine, do you know if the final model that was settled on, did it actually kind of play out to some degree or is it still off?

ROGER: Yeah, actually, we actually had an excellent check because at some point the mine was compelled by the State of Nevada to stop pumping for a period of time, there was some legal dispute, and the model tracked the rise of the water table almost perfectly. And basically how good it was for predicting a thousand years in the future, I mean, anybody can say. But for, you know, at least the time period surrounding the model and maybe 10, 20, 100 years in the future, it seemed to be a very good tool; both of them were.

TERRY: Okay. Other clarifying questions for Roger?

VLADIMIR: My question: Do you know how many iterations were completed prior to the model that produced the reasonable result?

ROGER: It was a long process, Vladimir,
and I know both of those models went through various redo stages.

VLADIMIR: I'm just familiar with the model which was the second slide.

ROGER: The last slide, you've seen that one?

VLADIMIR: And I work on this model and this model was verified each year -- each year during initial period of the mine, and this is no model problem.

ROGER: Yes, and there was a woman that was working on that. Was it Sandy?

VLADIMIR: Sandy Hutch.

ROGER: She came to our office and I showed her the map and then everywhere where the water table was above the ground surfaces I colored in red, and somebody from the mine was getting a little upset and Sandy looked at it and she says: That is too high. And we ended up getting a reasonable model. But she came out and looked at it and we worked together and produced a good model.

VLADIMIR: Thank you.

GRADY: On the slide here, Roger, you add that time is not a factor. Are you just referring to that model being a steady state model?
ROGER: In steady state models -- we had discussed the value of having a steady state model because everything -- we would like to see in the future how everything relaxes and comes to a natural state. I mean, regardless of what other projects may intervene in the meantime.

HALE: So, Roger, we've talked about this a lot in the past and I think, just to get the bigger idea on the table about -- I understand where you're coming from with the idea of the steady state concept, and the response we have here, I think it's important to inform, this is a transient phenomena that's occurring in this basin for the thousand-year period we're looking at.

So over a thousand years, which, again, is out to I would consider a pretty extreme period of time, but over that thousand years we're showing a transient change in storage in this basin over time. And so, that being the case, you're seeing water levels decline out there over a period of time.

A lot of this is occurring very slowly because it's occurring in very low conductivity bedrock materials surrounding the mine in the Santa Ritas bedrock copper field. So this is a very slow and long process of dewatering because of the low conductivity,
because of the low storage, because of the low stress that's being essentially put on the system; the stress being the evaporation -- the initial dewatering being for the 22-year period but then the longer term evaporation pit in-fill and evaporation.

So we've got a big reasonable model. We've got low conductivity over a large part of the fill system and we've got a pretty small sink in that system so it takes a really long time to propagate that storage change-out over time in that system. And we've taken it out to a thousand years and it still has a way to go.

As Roger indicated, when you get to a steady state, there will be no water coming out of storage. All the water's going to be coming out of reduction in ET, which is -- and in this model the two important components to this model are basically recharge from precipitation and evapotranspiration along the riparian areas along the Cienega Creek and a little bit in Davidson Canyon. So those are the two big in and out in terms of this model on the order of six to seven thousand acre-feet per year is the recharge input.

JON: Five or six.

HALE: Sorry. I'm not pulling those up. Let's just say in the large magnitude of five to six
thousand. So -- and we're talking about a long-term
sink in our model of like 160 acre-feet a year.

So it's -- from our perspective, you know, if
we run this thing out a thousand years, that's an
extreme period of time into the future. And during
that time that we're going to be showing storage
change, we're going to be showing drawdown of the
system.

But if we take the approach Roger's suggesting
and we run that thing out to steady state, then all the
water's going to be coming, you know, that steady state
may be 10,000 years in the future as we start to reach
that sort of equilibration point and, at that point in
time, there will be no change in storage, as you
indicated it will be coming from either reduction in ET
from discharge and coming from reduction of outflow
from the boundaries. And it will equal what's flowing
into the pit and being lost through evaporation.

So we can continue to discuss this steady
state idea but I think it's important to put in context
what is being considered in terms of a steady state
idea. That's thousands of years out in the future in
terms of equilibrium of the system.

TERRY: So I'm at a little bit of a
disadvantage here. I'm a forester, I'm not a
hydrologist or a geologist. But it feels to me like we've moved from defining the concerns into solutions and I'd like you to just hold those conversations for this afternoon.

What we really need to concentrate on right now is giving the Forest Service right now the opportunity to define their concerns with the modeling and plenty of time to discuss how we resolve those a little later, so if you'd do that.

The other thing -- Carter, can you hear us okay?

CARTER: Yeah, I can hear you fine.

TERRY: So if we people will remember Carter's on the phone, state your name when you're speaking.

ROGER: Okay. I was hoping to give Stan his half hour here.

STAN: Okay. I have a presentation also where I'm going to be kind of addressing more in general how artificial boundaries affect the kind of calculations that we're interested in here. I'm not saying that all of this strictly applies to the models here; it applies in general. The general principles apply but perhaps not the timing. We can discuss that this afternoon.
And, Carter, I have quite a few slides here that would be pretty hard to describe as I go. I'd be willing to make this available to you later if you're interested in it.

CARTER: Sure. If you could just email it to me after the fact, that would still be fine.

STAN: Okay.

CARTER: Thank you.

STAN: And I will try to describe --

CARTER: You don't have to worry about too much doing it during the presentation; I'm happy to see it later. Thank you, though.

STAN: I just wanted to start off with a look at the two models and what perhaps the concerns are. This perhaps, I believe, is the -- Montgomery & Associates, you call this the site model; is that correct? Regional model?

HALE: The eastside model, not the westside model.

STAN: Right. So we have a pit area here and then the concern is that along these boundaries we have some sort of head-dependent boundary. I believe that you guys use general head boundary.

So in the real hydrologic system there is no
boundary here, so this is something that's being added that's not real and, actually, that occurs around much of the perimeter of this model. So this is the greatest concern 'cause it's the closest to the withdrawal.

But when you look at a model like this, you wonder, well, if we're interested in looking at effects of these perennial reaches or evapotranspiration or springs, they're also simulated with head-dependent boundaries, how do these boundaries on the perimeter affect that? And so that's kind of what we're here to discuss.

And I think we've already started on a path of doing some more tests. You guys have been doing tests with your models and, hopefully, we can get a clearer picture of the possible effects of these boundaries. I think Grady's Tetra Tech model is similar but I believe it's got -- let's see -- constant head boundaries around the perimeter.

Again, the same lateral domains are pretty close and a lot more layers and the constant head boundaries are in different layers and that accounts for these layers; is that correct, Grady?

GRADDY: Yeah, yeah.

STAN: So that's kind of what we want to
look at.

SALEK: The lateral domain is identical in the two models.

STAN: The lateral model domain is identical in the two models. So -- and I'd be willing to take clarifying questions along the way if it doesn't bog things down too much, if you're willing to do that, Terry.

TERRY: Yeah, clarifying.

STAN: Okay. So I'm going to just explain the basics of capture by groundwater pumping, and I think most of the groundwater hydrologists know this but it's a good thing to review, show how we calculate that with a model using a hypothetical aquifer with all the real boundaries represented.

Then I want to -- for that same hypothetical system, I want to make an inset model that uses artificial boundaries and look at how that affects our artificial boundaries of capture and then compare the results of these models using real and artificial boundaries.

So those of us that are groundwater hydrologists know this name of Theis, C.V. Theis. Whenever you analyze a pumping test, we use a Theis equation. But he was also the first one to really
observe what happens when you pump a well and explain it clearly.

And that is that when you begin to pump, all the water comes from storage around the well so you're removing water from groundwater storage, creating a cone of depression, and water goes into the well. That's the only way you can get water into the well.

But with time that cone of depression goes out and you can do two things. You can increase the recharge to the aquifer and decrease the discharge from the aquifer. And the combination of those two things we would call capture.

And the way that we look at this graphically is something like this. We have the fraction of the pumping rate -- and this is pretty much independent of the pumping rate in most systems so you could -- the same fraction applies to different pumping rates.

Initially, when you start pumping, all of the water's coming from change in groundwater storage. But with time, as that cone of depression spreads out, we begin to capture inflow and outflow and that could be increased inflow from surface water, decreased outflow to surface water, reducing the evapotranspiration.

And the tendency, if you have enough water that can be captured, would be for this storage change
to go to zero at some time -- and this could be very
long time or very short time -- and all of the water
comes -- will come from capture and so it's important
to understand that these two curves are complimentary.
There's no other source of water to that well. So they
have to cross at .5.

And anytime that you have -- for any time,
like at this particular time, 60 percent or .6 of the
pumping rate could be accounted for as coming from
capture, this reduced outflow or increased inflow, and
40 percent for change in storage. So, for instance, if
you had a well that's pumping 100 gallons a minute,
60 gallons a minute would be coming from capture and
40 gallons a minute would be from the rate of change in
groundwater storage at that particular time.

And I've been really vague on the timing here
but this could be -- happen fast or happen over
millennia and it depends on the aquifer properties,
mostly the transmissivity divided by the storage
coefficient. We call this diffusivity.

The most important factor is the distance to
the connected surface water features. In the
analytical equations that -- for computing capture,
this distance is a squared term and the others are to
the first power. The aquifer geometry can also affect
the timing. If you have no flow boundaries that kind of limit the aquifer, that tends to speed up the capture.

But is everyone clear on this concept that these are the sources of water to that well and if you have available water for capture, you will proceed in this manner over some time scale depending on a lot of different things? That's very important that we understand that we can also look at components of capture.

For instance, this graph is from the San Pedro Basin model, the Upper San Pedro model. And I've broken down total capture into stream flow depletion, how much water -- reduced groundwater flow there is to the San Pedro River, how much reduced evapotranspiration there is, and those two add up to this total capture.

You could break it down further if you had springs or maybe different springs and you could look at capture for individual components for a system. But the total capture and the total storage change remain complimentary.

I'll just put in a plug for this report that's going to be coming out in a month or so. This is a circular, this comes from that. And it's really a book
on stream flow depletion by wells. It's going to the
printer within a week and we should have it probably by
early December. And we talk a lot about these concepts
but also about modeling, using models to compute
capture and depletion, and also some discussion in
there on artificial boundaries.

So the way with the groundwater model that you
compute depletion or the effects of pumping on these
features, surface water and ET areas, it's a fairly
simple procedure. You would first run the model
without the pumping of interests that you're adding and
you would record the flow rates upon which the
groundwater is flowing to this stream, how much is
flowing -- being removed by evapotranspiration, you
record all those flow rates and then you run the model
a second time. This time with the added pumping. And
you compare those flow rates with the pumping to the
ones without it. And you subtract them. And that
difference is the pumping-induced capture or depletion
for each of those features. So it's a fairly simple
procedure, it just takes two model runs to do it. And
I'm sure that you guys have been doing a lot of that.

So the characterizations of a well-constructed
model used to compute capture, one is you should use
all the real features so if you have springs that
discharge groundwater, if you have ET areas, streams where groundwater discharges, those should be put into the model as head-dependent boundaries so that when you pump water there can be a calculated change in the flow to those boundaries. So you include all the real boundaries; you try and avoid artificial boundaries, which isn't always possible, I'll acknowledge that.

But if you do have those, they should be much further away from the area of pumping than the feature -- the real features. So you'd like to see those kind of way far away so that, you know, the drawdown is going to hit your real features first.

And artificial boundaries can be of two types. They could be head-dependent flow, and that means that if you have drawdown that changes the flow into or out of the model at that boundary, or they can be a specified-flow boundary, including no-flow. And, in that case, the model can't change that boundary flow.

And these two boundaries kind of have opposite effects on capture. Head-dependent flow boundary will tend to underestimate it and specified flow will tend to overestimate it. And I think our recent conversations with Hale and Grady have been to kind of maybe bracket the answer using these -- they already did the one extreme but perhaps doing the other
extreme.

And then the -- lastly, you'd want the aquifer properties to be reasonably represented. That affects the timing, whether something's going to happen very fast or slow, assuming that you can get the geometry right as to how far the pumping is from all the features. That's something that we know from the land surface.

So I want to show this theoretical aquifer system. This isn't like the hard rock aquifer that we have up in the area of the Rosemont mine but it's just a general area of an aquifer surrounded by impermeable rocks. So this would be a real no-flow boundary around here and we're going to say that there's two springs, a pumping well in kind of the vicinity of these springs, and a little ways away there's a perennial stream. So I've made up some aquifer properties, and you may or may not like these; they're just done for an example.

So we want to use this groundwater model to predict capture through time as a result of pumping at this particular rate. And to do that with, like, MODFLOW, we'd break this up into a finite difference grid using a half-mile grid spacing here and we'd represent these features, the springs and the perennial stream, with general head boundary. And I used the
river package and we used the well package to simulate the well. And all of the boundaries in this model represent real features.

So when I use this, the procedure that I described to compute capture, it behaves as those curves that I presented originally. Initially, all the water's coming from storage, change in storage. We get capture from springs, capture from the stream, and total capture. And in 100 years we have not reached steady state but we're kind of approaching a steady state where this change in storage is going to zero and all the water is coming from total capture. So, as you can see, these total capture and change in storage, these two curves are complimentary; they cross at .5.

Now, let's do the same calculation. Let's make an inset model here, and we have the same aquifer properties and the same representation of these boundaries, same grid spacing, but we're only going to simulate this rectangular domain. And I'm going to put at these various spots constant head cells representing the artificial boundary of the model. And I didn't put it everywhere. I guess if I don't have it, that would be like an artificial no-flow boundary.

And so the difference here is that the pumping at this well, not only do we have to contend with what
it's doing at these cells, we have to look at what it
does with these cells which aren't real. And we're
interested in the effect that this pumping or that
these artificial boundary cells might have on what
we're really trying to calculate.

So when we run this model and compute capture,
we get something that looks like this. We get a change
in storage again starting, all the water's coming from
storage. And that goes down and actually reaches
steady state within this period but we get a lot of
capture from these artificial boundaries. So like
60 percent of the water is coming from boundaries that,
you know, should not be providing water in this
situation.

So when I've designed a model that can't
really behave like it should, this total capture from
real boundaries should be going up here and approaching
1 but because -- because of the water being supplied by
these artificial boundaries, we've -- this is capped at
.4 so we've got -- I mean, the design of the model, if
you're interested in looking at the ultimate effect of
this particular pumping, this model can't do it because
of that design. And so I would consider that a
fundamental flaw if you're really interested in
understanding that long-term effect of that particular
well on these features.

So just to compare, without artificial boundaries, you'd have this capture and with artificial boundaries you'd have this capture.

And there's other implications of this -- these boundaries also, and that is if we look at the cumulative change in storage, this green line here shows the pumped volume. So this is cumulative amount of groundwater pumped. And if there was no capture, the change in storage, the volume would be the pumped volume, it would follow this curve. The fact that this curve goes down here represents water being supplied by these -- the springs and the stream.

So this is the storage volume without artificial boundaries and with the artificial boundaries this is the storage volume. So, see, not only do you underestimate capture but you underestimate the volume of water being removed by storage -- from storage by the well.

And that makes sense because, see, you have these boundaries that are kind of holding the head up around the perimeters and you're kind of constraining the drawdown. That can't go down because of being held up by these boundaries. It's not being allowed to propagate out to the areas beyond those boundaries.
where there should be storage change over a much larger area. So if the -- you know, if the storage volume is being underestimated, then I would also -- then drawdown also is being underestimated by the effects of those boundaries.

Now, you might say that your situation was a little different; you don't have a well pumping at a constant rate. So I want to just briefly show you a different kind of boundary here. Instead of a pumping well, suppose that we would just have a sudden drop in head, and this might be the case of digging a pit and lowering the water table over a short time, or if you had a flowing well, you open it up so it's discharging at a constant level.

So instead of a well pumping at a constant rate, I put in a constant head here with instantaneous lowered head and then we look at what the capture curve looks like in that situation. And when you initially lower the head, you get a lot of water flowing in early because you have these very steep gradients going to that level of head. But through time that begins to settle down and so you settle into a kind of a constant rate of flow into that feature. And so I don't show what it would be at time zero but it starts out high, the outflow into this pit, and then it gradually
settles down and is approaching some steady value.

And I think the models that you folks have done for the site of the mine would have some resemblance to this in that you have some initial higher rates of inflow, probably both from dewatering and flowing into the pit, and then eventually, you know, you've mentioned a steady state ultimate rate of inflow.

And you can look in this situation what the capture from the stream should be and the capture from the springs. But the important thing is the total capture that, as this system comes to a steady state, these two curves should merge so you should get -- if you ran this out long enough, you'd have -- and I think Hale just said this in words earlier, that eventually you'd get to a situation where, you know, all of that outflow to the pit is being accounted for by a change in ET and maybe a few other things. So these curves should be -- should actually meet way out in time as you reach a steady state.

But with the artificial boundaries in that second case where I did the little perimeter with some constant head cells, this would be your outflow to constant head to this pit but because you're getting effects from these, you know, water being supplied by
these artificial boundaries, you can't -- these two
curves will never meet.

This is just what we need: music to go along
with the model discussion.

(There was an interruption due to music coming
through the loudspeakers in the room.)

TERRY: We'll try to get some different
music on here; bear with us.

STAN: So the artificial boundaries are
a problem for this because it doesn't behave like it
should. And also notice that it comes to a steady
state much, much faster. So within this period it's
probably at a steady state, nearly a steady state,
within this period. So the timing of it is different.

So I just have this one summary slide, the
problems that head-dependent boundaries can cause. The
ultimate total capture is reduced by the amount of
water that these artificial boundaries are supplying.
So that's something you really would want to look at in
a model. The timing of the total capture and capture
from individual features may be influenced. The
artificial boundaries kind of tend to stabilize things
a lot faster and they come to perhaps an earlier steady
state solution.

You could actually switch -- I didn't show
this, but -- I mean, I showed it but I didn't talk about it. The capture from individual features may change because of the artificial boundaries. So if we're interested in the springs and the stream, maybe the proportion of capture from each of those could be different, could be affected by the artificial boundaries.

You'll tend to underestimate drawdown and aquifer storage change because of the artificial boundaries. And if you have a model in which these influences are significant, there's no real way to tell what the true answer is from that model. I mean, the best you could do is perhaps bracket -- bracket it, you know, like we're trying to do with the specified flow versus specified head.

And if you do have models with artificial boundaries, they should undergo rigorous tests to study the effect of those boundaries on what you're trying to compute.

MELISSA: So just to put this into context for people who haven't necessarily read the modeling reports, where are you seeing artificial boundaries versus the nonartificial boundaries, to try to link this with what we're actually seeing in this model?
VLADIMIR: And if it's possible to state what area of the concern, I understand boundary and timing, but can you be more specific, what is the concern with existing numerical groundwater models you see?

STAN: But your question -- you want me to relate it to these models; is that correct?

MELISSA: Yes, please.

STAN: All right. So, my experience with this is through Roger. We've been discussing this for probably a year or so, and I don't have the ability to run these models 'cause they're with MODFLOW surfact, which is not a USGS model and I don't have it. But Roger ran the hypothetical test of, I believe, the Montgomery & Associates model which looked at steady state and that would be looking at these curves way out in time when the system has reached a steady state. And it looks like the capture from the artificial boundaries with the Montgomery model at steady state would be roughly, was it .5 or .48?

ROGER: 51 percent.

STAN: Roughly 50-50. So half of the water is coming from artificial boundaries and half from real.

MELISSA: And to clarify, the western
boundary is the artificial boundary that we're referring to?

STAN: Well, actually, all of them. But that's the close one so -- now, it might be that this time scale is completely different, that this is 10,000 years or 100,000 years, and that you guys are looking at, you know, what's going on right here, you know. That's the kind of discussions we need to have.

And, actually, the question of whether do we want to look at a thousand years or steady state, that's almost kind of a question that's above me, you know. I, as a hydrologist, I'd want to be ready to give decisionmakers an answer as to what's going to happen in a thousand years or what's going to happen at steady state or some other time.

ROGER: And, Stan, you made some point of what proportion of capture from artificial boundaries was maybe acceptable. And how could that relate at this point?

VLADIMIR: Let me also ask. If I understand, you're looking on the percentage of the -- or proportion coming from the artificial boundary but what if this percentage will come in 200 years?

STAN: That's -- what level are you all willing to live with? So bear in mind that whatever
percentage that is is not a random error, but it's an underestimation of the effects on real features. So if it's 10 percent, maybe that's okay, you can live with 10 percent. If it's 50 percent --

VLADIMIR: Let's go back to the timing.

HALE: It does come back to the timing here and maybe someone could do a little bit of a discussion here for Stan, you know, how we got to a thousand years; we started out at 250. And timing -- I mean, I agree with everything you're saying, Stan, but timing truly is -- the length of this period truly is at the heart of this whole discussion and so, as Stan indicated, he hasn't looked at our models and everything he's showing here is absolutely correct.

Our models are a much longer time scale and the boundaries were scaled to be appropriate to that type of time scale. So at this time maybe, you know, if -- it would be good, I think, to get some handle on this time thing because I think in all of our minds a thousand years out was an extreme length of time to cover everyone's concern. And that's where we resolved it at. Our model can go to 10,000 years before it gets close to steady state. And so that's what's on the table here I think is a big part.

TERRY: And is that something you're
going to discuss more in your presentation?

HALE: Not necessarily. I mean, I can show that in a thousand years the boundaries are not an issue and that's the extent of our analysis. If we want to have a further discussion about the appropriateness of 250 years or a thousand years or steady state, that's really, I thought, had been decided. And if that's on the table, then that's a good discussion to have.

TERRY: Okay.

STAN: But we've been corresponding by email about perhaps you making some curves something like this.

HALE: I've got some curves certainly, yes.

STAN: That would -- I think that will be a good discussion, is how much are you affecting -- how much water is coming from the boundaries in these periods.

HALE: Right, definitely.

STAN: That would be good.

HALE: But they're supporting that we don't even see boundary flux changes for 100 years out so it becomes a timing issue here.

STAN: And then I'd want to see the
boundary flux change that you do see at a hundred years, how does that compare to the real features, the change in flux to streams and springs and ET.

HALE: Right.

STAN: So comparing those numbers --

HALE: Right.

STAN: -- is of significant importance.

Vladimir, did I answer your question?

VLADIMIR: Yes, but maybe for the positive result of the discussion I would like to bring one note.

The model is extrapolation, right, what we learn in the field and how we're going to extrapolate in the future, and timing is extremely critical. And I start to think that Montgomery did very good job trying to stress system during one month, and we're trying to observe for the most of the groundwater system for one month and we try to extrapolate. How long do you extrapolate? Numerically you could million, million years, but to what time extent you will believe in your prediction?

STAN: Well, you know, there's some -- some things that I would be very confident in regardless of the model and that would be this result. And that is that the total capture will eventually
equal, you know -- as Hale says, it will equal what's being removed, and you don't even need a model for that. So what you can argue about is the timing. Well, you know, is your transmissivity too high or too low?

VLADIMIR: But in your case, it's 100 years. But what if you numerically get in one million years?

STAN: Well, it would have reached steady state by then, right?

VLADIMIR: No. If in your case it would reach steady state in one million years, will you believe in your prediction?

STAN: I don't have a problem using models in that way. I mean, that's something you can tell people: Well, our model says that it's not going to be in steady state until a million years. We don't know --

VLADIMIR: But I'm modeler, too, and I can run this model for million years but the question: Will I believe? If I collect all data, stress system by one month, will I believe my prediction in one million years?

STAN: In other words, since you're collecting data over such a small time interval, are
you --

VLADIMIR: It's related. For the stress of the system for pre-mining condition is a relatively long time, one month. Normally people will do pumping test five days, ten days at max. Some hydrologists doing tests during 24 hours. How are you going to extrapolate there? And for me it's very long period time of the stress. How you extrapolate this in millions years or thousands years? Model can probably even handle infinity but will you trust this model or not?

HALE: And just to clarify what Vladimir's talking about in terms of one month, we did a 30-day multi-well aquifer test. And so the model is calculated to steady state conditions, which essentially the system is in a quasi-equilibrium, and then we calibrated to this 30-day pumping test we did to stress the system.

And so what Vladimir's point is, so are we taking a one-month stress and creating the system and extrapolating this to, I'm just throwing out there, it may take 10,000 years for our model to reach this point of equilibrium and extrapolating that out for a 10,000-year projection, and that's where I think the concerns arise.
STAN: Yeah.

MELISSA: I think what this probably goes back to is one of the things that Jim was trying to get out is in the big picture of things, you know, how much for his informed decision-making, how much can this model feed his big picture concept of the effects of the project.

So it definitely goes back to kind of what we're going after, Jim, and I think more of the discussion on that could probably be moved to this afternoon. I wanted to make sure -- I didn't want to cut you off but I want to make sure that when you're speaking about the concepts that we keep relating them back to what Jim has to make his decision on so that we understand what you're seeing and where some of the issues are.

STAN: Yeah.

JEAN: So, Stan, this is Jean Calhoun. The timing is critical and so if the model assumptions are correct, perhaps the models are accurate with respect to the real features and capture, springs, seeps, et cetera, but what if some of the assumptions are incorrect? The transmissivity of the system, for example. Are there any features that could be encountered that would speed up that capture? Such as
karst topography, fracture fault system that is much more transmissive than the models are showing?

STAN: Right. So what most of the discussion here is about is timing, of what is going to affect the timing. And I have to admit, you know, I haven't had time to, you know, rigorously review these models, you know, and we were asked to look at the EIS and we looked at the model documents and some of my colleagues were more concerned about things like, you know, fractures and karst and whatnot, which can affect timing.

But the thing that jumped out at me is this kind of a fundamental design of a model that doesn't allow you to compute what the ultimate capture should be. And so I would think that if -- with something this controversial or contentious, however you want to say it, you would a want to make it as solid as possible and not allow, you know, criticism or questionable -- anything that could be questioned. So I think a good design of a model would be one that didn't allow these questions about these artificial boundaries supplying water that don't exist.

So what I've kind of been addressing is a separate issue from the timing. And -- but, you know, maybe if there is some rule that says we're going to
look at a thousand-year period or 250-year period, you know, that's relevant to this, and that maybe -- maybe you don't want to look at ultimate capture, which you can't do with these models, I don't think. I don't think the models are set up for that.

JIM: This is Jim. If I'm understanding correctly here, the timing is critical because if you have an artificial boundary, the effects of that artificial boundary may not come into play until a long period of time.

STAN: Correct.

JIM: Whereas, with the models that are being used right now, the actual effects up to a thousand years may be -- we're not going to make any assumptions yet, but may be accurate because those artificial boundary influences wouldn't kick in until then.

STAN: Right.

JEAN: However, if you address the artificial boundary concern and the steady state concern, both of those concerns, then you provide some protection in the event that the timing is off and there is some -- there are some real features, such as fracture systems, et cetera, that do the capture quite a bit sooner. So if you address those two issues in
the modeling, that will help address the other concerns that have been brought up about the models.

TERRY: So it's feeling to me like we're kind of wrapping up the part about articulating the problem or the concerns on the Forest Service part and moving into the next step.

I'd like to ask Salek, and Roger, whether you guys have anything to add.

SALEK: Do we have a map of like cone of depression?

STAN: I could bring up one of the reports, I think.

GRADY: You're talking about our models or --

HALE: You're going to give our presentation, Stan?

STAN: That might be easier.

HALE: Just joking.

SALEK: Since he's already hooked up.

ROGER: I think the concern has been well framed.

TERRY: Okay. Chris, I want to get back to Dan 'cause he had his hand up.

DAN: Roger, when you looked at -- when you do your steady state analysis and you came up with
that 50-50 artificial boundary versus feature, did you look at the geographic distribution of which artificial boundaries, west side, east side, where was the -- where was the water coming out of the --

ROGER: No, but it's much easier to do the cumulative mass balance from the model and you can do it, you know, just in a few minutes.

However, if you look at their models and the differences in them, the -- on the east side you hardly ever see any differences. So the likelihood that those fluxes are coming from the eastern or northeastern or southeastern boundaries is pretty remote.

So it's most likely -- and it's still easy enough to get those fluxes because they're reported in the model in a very detailed manner. So you can do a detailed analysis. You could do it on a cell-by-cell basis if you really wanted to. But basically it was the cumulative information from each model, one without pumping and one with a minor amount of pumping, and both steady state.

DAN: Thank you.

TERRY: Chris?

CHRIS: Actually, Salek can go ahead.

HALE: And, Dan, I was going to say, we actually did the runs Roger did, and there's a
June 29th response letter this year to the Forest
Service that those are in there, and it's showing where
those are coming from in the boundaries and the steady
state.

SALEK: This is what I was looking for, the maps of the thousand.

STAN: This would be for -- this is 100 years.

GRADY: We're going to talk about these.

SALEK: Yeah. I just want to show you one thing about it real quick. So I just want to bring up two different points here. One is, the first real point is, is the domain boundary and the location of the pumping area. I mean, obviously this is the -- what we've been talking about here this morning. I just want to kind of bring it into, for me, like into simplistic terms.

The point that Roger showed earlier, the mine was essentially in the center of the domain, and regardless of where the mountain ranges were, he showed I think it was six basins.

Roger, what was that other one? It was like a six basin wide domain. This is essentially just one basin going across this.

So a traditional model, and my understanding
would have been that either you have a -- the mountain range here, you have a divide, a no-flow boundary there, or you increase your domain to where the actual effect doesn't touch the domain.

And so there's a couple of different ways to do that. I mean, so in a very simplistic, traditional sense, this particular domain wasn't, in my -- from going through all the steps that we've done in this process, essentially, the domain was skewed to one side, if you want to call it that, so the domain was very close to your pumping area. And so, in a way, it felt it was, if you want to call it, it was nontraditional; it wasn't in the center. And so, therefore, your domain is way on the outside of any kind of influence.

So it was skewed, which isn't a problem if you have essentially a no-flow boundary on the mountain range, which was discussed, and the actual mountain range itself here. The values attributed to that mountain range were so low that it was essentially going to act as a no-flow boundary. So, therefore, the domain could be close to the pumping area.

And now we're talking about the timing. In 50 years this pumping area won't affect and won't go through the mountain and affect that domain. But as we
see in running these models into the timing, the long-term, you started getting into 100, 1,000 years essentially, now the cone of depression goes through the mountain range, which was essentially supposed to work as a no-flow boundary and does affect that domain boundary.

And so, if we were to extend this out even further into the future, whatever we're talking about, 2,000, 10,000, a million years, what would it be, either this domain boundary would need to be another 20, 30 miles away or not.

My point is, is this was, to me, set up as, if you want to call it a nontraditional domain boundary in the sense that there wasn't a line along the mountain front and -- so that would have been what Tom Myers did, right? So that was very, very traditional, which has its pros and cons.

So this was set up nontraditional that way. But it ends up -- it shouldn't -- we were considering it to be non -- to be nontraditional, but it wouldn't be like that unless the cone of depression actually got to the domain.

And essentially that's what it did in this particular case. And that's why we're all here talking about this 'cause the actual cone of depression is
touching the domain. Traditionally, this pumping center would be in the middle.

So from a Forest Service perspective, the whole point is is we're in the process of looking at a, if we want to call it this, a nontraditional domain because it's not in the center; it is off to the edge. So that's just my first point I wanted to bring up.

The other part is, if we're looking at a thousand years, there's been discussions in the past about these different timing, 50, 100, 1,000 years, because of this domain issue and the cone of depression hitting the domain, now what happens on the outside of the domain is, in essence, unknown.

So this is a separate secondary thing because the cone of depression touches it and it is essentially cut off. So that is what happens when you get into a nontraditional model set-up. If we're going to call it that in the sense that it's not if we're just looking at 50 and 100 years, but if we're looking at longer term then it becomes nontraditional. So that's why I'm trying to bring it back.

Because we're looking at a thousand years and that's what we're disclosing in the EIS, that's when the rub starts in on the domain and the boundary conditions and all of these things.
So I'm not sure if -- I just wanted to think I made sense to myself, whether or not I made sense to everybody else, but that is essentially where -- why now, if we're looking at the boundary conditions and the actual numerical justifications of this boundary being acceptable, okay?

TERRY: Clarifying questions?

MINDEE: Do we know at what point in time that boundary influence comes into play and produces these questions?

SALEK: I think it's -- I'm not 100 percent sure, maybe these guys can talk about it, but I think it's -- obviously at the thousand it's well influenced. In the 100, somewhere in there, 50 to 100, somewhere in there.

But I'm not 100 percent sure, and I think really what it came down to is just my own opinion on this is the boundary and kind of in a way surprising that the cone of depression actually did make it all the way to the boundary, to the domain, when it felt like that the values that were attributed to the mountain range there were so low that how could it do that? And so essentially -- but it did; numerically it did. That's why we're in this position.

So that's a whole different viewpoint but I
want to bring it up. But that's kind of why we're looking at this part of it is this -- I'm going to call it nontraditional.

TERRY: So it feels like we're about ready to move off of this and, Mel, could you kind of briefly go over what you've captured on the flow charts and Stan and Salek and Roger?

MELISSA: So the Forest concerns, I have the boundaries matter, that the domain is too close to the estimated effects, and that you can't estimate the effects outside the domain boundary.

If stress impacts a constant head or general head boundary, it may need to be reformulated.

Roger stated that the goal was to work towards the steady state.

And then Stan talked about the artificial boundaries need to be rigorously tested because it can offset the capture from real boundaries and features.

And the timing is critical. And then you stated the percentage from the artificial boundary equal the percent underestimated impacts.

TERRY: Anything to add? Okay. So what I would suggest, we're going to break for lunch in about an hour, and you need to set up for your presentation. So if people need to take a break, let's
take a really short break now and we'll get that
PowerPoint set up and be back here in -- say 20 'til.
That's about six or seven minutes.

(A break was taken.)

TERRY: We're going to move into the
next agenda item. We've got an hour scheduled for
this.

On the phone, do we still have EPA on the
phone?

CARTER: Yeah, I'm here.

TERRY: Bev, are you on the phone yet?

Anybody else on the phone?

Okay. So, folks, if you have questions, make
sure you say your name first.

So with that, we're going to turn it over to
Grady and Hale to give a presentation on their recent
modeling work.

GRADY: Kind of like we decided to do
this, Hale's got a PowerPoint here and it goes into
some of the basics of how the model was set up and some
of the decisions that were made through the process and
a little bit of that background information, make sure
we're all on the same page with that.

And then the focus of it's going to be
discussing this latest test that we did with -- the
sensitivity test with the specified flux boundary and showing how that compares to the base model boundaries that we have and kind of the differences we see and then what changes over time with that.

So Hale's going to do his part and then after he sets that all up and goes through his, I have some slides we'll do. We'll go through the Tetra Tech model that results from the same thing as that.

And, really, kind of what's been said, this is the bracket. So this is kind of a worst-case scenario. If the boundaries are affecting the results, this is what it would be with the specifying the fluxes going out of the model, so --

HALE: So I know some in the room have not really had any -- much exposure to the model. We figured it would be good to do a quick run-through of a brief description of how the model was developed and constructed and how we got to putting out the EIS report back in August of 2010 and the results of the model in it.

And then we'll essentially do what Stan's been discussing, where we will vet the boundary conditions, if you will, and try to demonstrate that, for this particular set-up of the model and this particular hydrology, the boundaries were appropriately set for
the analysis. This was meeting objectives. And I'm going to rush through this so just yell at me and stop me. I don't want to get bogged down. This was a four-hour discussion back in December so there's just no way to go through everything.

This is our model domain and, again, we're located over east in Cienega Creek Basin east of the Santa Cruz Basin. And the objectives of what we did for the EIS modeling, we were simulating a 22 -- actually a 22-and-a-quarter-year mining period and then we're simulating for a thousand year post recovery period. Through equilibrium there is sort of a misnomer in the context of what we're talking about today. The pit lake starts to approach equilibrium after a thousand years as far as the lake level and the lake inflow but the groundwater system in the larger regional model did not. We're also -- also it's determined the pit would be a hydraulic sink.

And, finally, to project groundwater levels impacts to the surrounding systems including evapotranspiration, reduction in stream flow to surfaces features such as Cienega Creek and Davidson Canyon.

This is our model domain; Salek had it up earlier. Again, we see here is, I think at least at
this time, the locations of the tailings of the waste rock and the pit location there in the yellow. And then the extent of our model, features here that are important are Cienega Creek going through the central part there and then Davidson Canyon through here upwards towards the mine.

The hydrologic features are a big component of this. Again, we're talking about the aquifer parameters that will affect how the drawdown propagates out through time. This system is a basin fill, deposits here, this is the Santa Rita Mountains here, which is -- the core is a granodiorite, very low permeability to no permeability, and then we're into volcanics, fractured volcanics, sedimentary basin -- bedrock complex in the Empire Range here.

Again, we are basically looking at a bedrock complex throughout this area trending to a tertiary and ternary basin fill system out to the central where Cienega Creek bisects through it. Our mine is right up -- our mine is right here. We are in the bedrock complex, we are in the very low conductivity fracture rock system. Precambrian granite diorite is the core of the Santa Ritas. To the northeast and north we're into the -- and to the east somewhat from the mine we're into the more bedrock. And then to the east and
the central part of Cienega Creek Basin we're into basin fill deposits.  

And, again, we've done quite a bit of hydraulic testing out there, pumping tests, and the basin fill deposits near the mine are strongly cemented, very low conductivity, acting as an impediment for drawdown mitigating out from the pit. And we tested the heck out of this. So someday we'll write a paper about it.

Locally, the conceptual model, we are in a fractured bedrock flow system. We're assuming that is equivalent porous medium. This is all supported by testing we did back in 2008-2009. Low conductivity bedrock system, Santa Rita again. The granodiorite is very low conductivity and that mitigates any propagation to the west. And low conductivity of the system mitigates propagation to the east as well.

Regionally, the system is predominantly groundwater storage and basin fill material. The basin fill material, again, is magnitudes higher in conductivity than the fractured bedrock. Pumping in the system is really insignificant. We're in a quasi-equilibrium system in the region. Precipitation recharge is the overwhelming source of water to the groundwater system. And evapotranspiration is the
predominant discharge for the groundwater.

Both Grady -- we used MODFLOW surfact model, which is a finite difference model, and we used the LAKE2 package for simulating the development of the lake. The model may encompass most of Cienega Creek.

And our boundary conditions, in our model we used general head boundaries which -- and we used constant head but we used general head boundaries which allowed the head at the boundary to vary some but it's still a -- it's a head-dependent variable flux boundary. So flow across that boundary can change in response to drawdown that's occurring in the model.

Stan talked about this. Again, everything Stan has identified is correct in our model as far as our boundary. Flow across that boundary can change due to drawdown that occurs internal in our model domain.

So --

CORI: Both models used the same code?

HALE: Yeah, we both used surfact. He used constant head all around, we used general head which provides a little bit of mitigation but ultimately --

So this is the grid map for our model. Again, we've got really fine grid cell spacing in the area of the mine. It's a very difficult numerical solution
solving for this lake development and drawing water
down 2,000 feet in a bedrock complex that is extremely
low conductivity. The vertical gradients are nasty and
so it's a really difficult numerical simulation. We
had a very tight grid cell spacing here.

Back to the whole idea of the boundary issue
here. So we started out with the whole idea that the
Santa Ritas were essentially no-flow. But then -- and
we even started with the idea like Myers used it, we'll
just use the topographic high here for the model
boundary.

But stepping back, we are modeling a system in
bedrock. We are modeling a system right in the middle
of the mountains. So I think, you know, we felt like
the idea of saying, well, there's this imaginary line
where the mountains are no longer permeable is bogus.
And so we have testing value here -- testing values
here in this area. We extrapolated those ideas of
conductivity into the rest of the mountains and felt
like it was more, not -- less contrary, if you would,
to say if we are modeling a mine in the middle of the
mountains, we're going to include those mountains in
the flow system.

The idea that we took it out to here -- this
is the core of the Santa -- this is the continental
granite diorite. This is ten to the minus four feet per day conductivity. That's six magnitudes less than a conductivity in the basin fill deposits. That water's going nowhere.

But after a thousand years, you know, you create enough of a head differential adjacent to this, even ten to the minus four feet per day, some water's going to seep through the stone. And in our idea we felt it was appropriate to at least show this, and we met with SRK and we had lots of back and forth meetings, it felt like the right thing to do was to put some low conductivity material, essentially nonpermeable, in there that would be representative that we are modeling a mine in the middle of bedrock.

So trying to address the idea that we're off center, and I understand where you're coming from, we're off center but we also have along here a -- this is the edge of the basin fill. The edge of the basin fill deposits are right here. So you're into the Tucson Basin. What you've got going on here though is, again, very low conductivity bedrock which we're simulating in our model.

For example, you've got, this is the Helvetia Mining District down here. You've got underground workings into the mine from 100 years ago. You know,
none of those are flowing, none of those are indicating that you've got water moving from the much higher elevation waters over here to this side. We're hundreds and -- well, we're probably 500 or more feet, the water levels in the mountains here, above the water levels over here. None of that's flowing through the mountains. It's not showing up as discharge in this underground water table. It really is an impermeable boundary for practical purposes.

So, you know, I'm trying to give you an idea about the considerations we were going through when we set this model boundary. But for practical purposes there's very little water moving through there. And we'll show that in our results. And that's what we tried to show in the previous memos. We tried to show the quantity of that water running across the boundary as being very small but maybe what we should have done is gone to these drawdown plots and said, hey, it doesn't affect the drawdowns either way. So we'll show them.

CHRIS: Hale, can I ask, why right there? Why not a mile further out or 10 miles further out?

HALE: Well, at this point in time, you really have no hydraulic connectivity. You know, the
way we see the system occurring, if you can picture the west escarpments of the Santa Ritas here. And so what's happening here is you've got mountain recharge occurring up in these areas and it's essentially gravity flow through shallow fractures down, and gravity flow through those shallow fractures until it gets over here to what you consider the saturated basin fill aquifer over there.

So there's really not even, in our mind, any significant hydraulic connection through here; it's shallow. And the best way I think I can say, shallow gravity flow. It's moving, which was mountain front precipitation recharge here on the west side of the topographic boundary and moving as shallow flow until it gets over to essentially the basin fill aquifer over there.

Does that make sense? So in some sense it really is a boundary. There is no hydraulic connection there. Ultimately what we're doing is, as we start to capture a little bit of that water, we're robbing that mountain precipitation that otherwise would have flowed into the Tucson Basin.

JEAN: So, Hale, this is Jean. Why not make that a no-flow boundary then?

HALE: Well, we -- again, I think in the
concept of no-flow, ten to the minus four feet per day
is about as close to a no-flow as you can get. But we
even did a sensitivity at ten to the minus five feet
per day and it's effectively reducing -- you know, we
had, I believe it was over the course of a thousand
years, we had 42 acre-feet a year of water come into
the model as a result of the benefit of this variable
flux boundary. And that was for the whole model
domain. Most of it was coming from the west side
actually, more up in the Tucson Basin area. Most of it
was coming in through here.

When we dropped it ten to the minus five feet
per day, you know, I mean, people who deal with nuclear
repositories and things like that, what numbers are
they at? Like, I don't know. We're getting awful
close

MARK: Yeah, they use centimeters per
second.

HALE: At ten to the minus five that
change in flux across the boundary reduced to, I
believe, 31 or 32 acre-feet a year. So if we went to a
no-flow completely, I think it -- first off, it would
have just been no-flow just -- and I'll show you a
hydrogeology map a little bit more clear -- it would
have been just for this area where the granite diorite
is the predominant component and we would still have
flow over here because it was more representative of
what we're mining in. We had some stability problems
making it no-flow.

SALEK: Are you talking about the domain
or the actual maps?

HALE: No, you're talking about make it
granite diorite no-flow.

JEAN: Yes.

HALE: And we had some stability
problems with no-flow that close to this 2,000, 2,500
foot immediate sink when we pumped it down. So our
position here I think was let's consider that there is
some movement in the bedrock. And, again, this is
discussions back and forth with SRK and the Forest
Service and the formulation of this whole thing to get
it to the point that the amount of groundwater moving
across there is essentially negligible, and I think we
can demonstrate that.

STAN: This is Stan. Could you clarify
what that number means, 48 -- was it 48 acre-feet per
year or something like that? Is that from all of the
boundary?

HALE: Yeah. I think it was
42 acre-feet per year was the net -- after the thousand
years, the change in boundary flux.

  STAN: Oh, that's change, okay.

  HALE: So either a decrease in outflow
or an increase in boundary inflow was 42 acre-feet a
year.

  STAN: Okay.

  HALE: And we won't even see any change
in boundary flux for 200 years after the mine.

  STAN: Okay.

  HALE: Okay. Again, we talked about
conductivity. We did quite a bit of testing out there
and this actually was part of that. The central basin
was considered as a water supply back -- back in the
'70s and '80s this area was investigated for purposes
of a mine and there was quite a bit of testing done for
a water supply out in Cienega Creek Basin. So we have
aquifer testing data in the Cienega Creek area for
those when they were investigating a water supply for
the mine the first go-around on this site. And then we
have our testing in the mountainous areas, the
fractured bedrock that we did back in 2008 and 2009.

  SALEK: So the testing you did on the
pit side, there's -- like Vladimir was talking about,
there's a 30-day pump test and there's a -- ten wells?
30 wells?
HALE: So we did a five-well pumping test stagger start but they're all going at the same time eventually. I think it was 47 monitored wells and we spent about three months trying to analyze that data. Predominantly what we were seeing was no response. We monitored the drawdown and recovery, so it was a two-month test essentially. I'm trying to get some idea about directional and we were monitoring vertical. We had a lot of piezometer completions to depth. Some of the wells had five different discrete piezometer completions.

We got pretty carried away and at the end of the day we had some -- we had a sense of some of the major fracture components of the systems and some of the, if you will, compartmentalized higher density fracture rates. We had a sense of that from the drilling. We were able to tie two of the big fault features into the results of the aquifer test response. Those are representative of the model.

So that was a pretty laborious process but it did give some of the validity to the model. Locally we are able to produce some of that local response from the 30-day test.

SALEK: But there were a lot of wells that were put in brand-new --
HALE: Yeah, 36 wells were put in.

SALEK: -- around the pit area and around it. How about on the other side of the mountain range?

HALE: You mean in the Helvetia area?

SALEK: Yeah.

HALE: We did not put any wells in the Helvetia area. Again, back to the idea of what we considered the granite diorite to be. You know, I don't expect there ever to be any impacts west of the granite diorite.

JEAN: Hale, how far east of the pit area did you put in exploratory wells and how deep were they?

TERRY: While he's pulling that up, would the folks on the phone make sure that your mute buttons are on? We're getting a little noise from paper shuffling or something in here that's a little distracting.

HALE: I didn't bring all that and actually one of our other partners led all the drilling program. So what's that distance? We put in -- so, you can see the RP wells here. Two and a half to three miles to the -- that's the furthest one out that we put in. I'd have to go look up what the depths are. Some
of them were up to 1,500 feet deep and some of the shallower ones were three to five hundred feet deep.

JON: Hale, it was 2,000 feet deep right along the backbone area and then outward it got less deep.

LARRY: Hale, this is Larry Cope. I want to make sure that the 42 acre-feet difference in flux, boundary flux, 42 acre-feet per year, is that at the thousand years?

HALE: That's an instantaneous rate.

LARRY: An instantaneous rate at a thousand years?

HALE: Yes.

LARRY: Because that equates to about 15.6 gpm for the entire boundary of the domain. So, to put some context in that number, that's a small number.

ROGER: How does that compare to the flux off of the pit lake at that point?

STAN: Yeah, it was 160. So it's 42 -- it's about a quarter of the flow to the pit according to their numbers. It's kind of the artificial boundary at a thousand years.

MINDEE: And what change? I missed that part.

HALE: Say that again.
MINDEE: What changed? What did you do that you got 42 acre-feet versus 160? Was this one of the sensitivity?

HALE: No, that's -- I jumped ahead. I apologize. Maybe I'll get you that. But I was just talking about a thousand years of the pit sink, hydraulic sink being there. And after a thousand years with drawdown propagating outward and at a thousand years it actually captured some of the outflow from the model boundary per what Stan was discussing.

Does that help?

MINDEE: Mm-hmm.

HALE: Okay. So this is, again, some quick view of the hydraulic conductivity. Again, very -- this is greater than ten feet per day conductivity in the basin fill ranging down to -- down to, as I say, there's a little bit of ten to the minus four here. We've got a little bit higher conductivity in Layer 1 of the Santa Ritas just given some shallow fracturing, some weathering, that type of stuff.

But if you go to Layer 2 you really get the gist of what I'm talking about. So we quickly get out of the basin fill and we're into tighter Quaternary alluvium and then we get into very tight cemented basin fill and then we're into the mine which is in a
sedimentary bedrock formation. And then here is your continental granite diorite, which is ten to the minus four feet per day.

So we really do have, most modelers would agree, in effect a no-flow condition here. There is some water flow to it if you put that much gradient on it. If you put a 2,000 foot head gradient difference across there, you're going to get some water moving through there.

And so this is just showing down to the bottom of the model again. We're into underlying bedrock, symmetry bedrock formation and this is the Santa Rita granodiorite condition here and the volcanics.

Sections. Again, this is -- quickly, this is A prime, which is just a quick breeze through -- a quick snapshot through a small part of the model, but just to give you a sense of some of the complexity that we have in the model trying to represent what we have determined. This is your granodiorite. This is your Paleozoic symmetry and also symmetry, a little bit that's --

SALEK: So is that on the domain?

HALE: That's in the model domain.

SALEK: That's the edges of the model domain?
HALE: Yes.

SALEK: So it doesn't go actually out into the alluvial?

HALE: Oh, no, no, this is just A prime.

SALEK: That's what I'm asking.

HALE: It's there to there, I was just --

CORI: Just the north end of the pit.

SALEK: I'm just making sure.

HALE: We simulated stream flow, tried -- the model was calibrated to stream flow for Cienega Creek. It was actually also calibrated for what used to be in Davidson Canyon but has not been a perennial stream flow in Davidson Canyon for five years.

JON: Sounds about right.

HALE: That number escapes me. For a number of years. And, again, stream flow is occurring as groundwater discharge to the stream. That's what we're simulating is groundwater discharge to the stream.

STAN: Hale, before we go on to these, we talked about hydraulic conductivity but storage properties are equally important in the propagation of drawdown. Is that something that's coming up?
HALE: Yeah. I think I've got --

CORI: We've got a lot to go before lunch.

HALE: Yeah, we're trying to -- so much information --

JON: Where is --

HALE: Am I missing it? Late night cut and pasting on PowerPoint is just not a good thing. Jon will pull it up, Stan, and give you a range.

STAN: Yeah, we can discuss that later. That controls the timing also.

HALE: Yeah, I -- yeah. I've got that slide but I guess I pulled it.

The other -- the big component is discharge from the system. Groundwater's recharging -- precipitation is recharging the system and it's discharging predominantly through evaporation via the riparian areas along Cienega Creek and Davidson Canyon. So that is the predominant groundwater discharge to our flow system here, and it becomes very important because evapotranspiration is a variable flux boundary, a variable flux outflow. So it's head dependent and if you lower the head slightly, you will get a slight decrease in the evapotranspiration. That's the way the natural system functions. That's, you know, that's
what, you know -- that's what you see in the Tucson Basin with mesquite bosques going away as the water levels drop, those type of things change. Evapotranspiration becomes the valve that changes in response to the decrease if you take water out of storage.

Model calibrated pretty well. We calibrated steady state. We had almost 400 groundwater targets. We calibrated to flow in Cienega Creek and Davidson Canyon and calibrated to estimates of evapotranspiration so there's a lot of good data out there from PAG on evapotranspiration rates for the riparian area, we calibrated that as well. We also did the 30-day multi-well pumping test as I described previously.

This is the steady state calibration, very good statistics on this calibration. I showed you this map already. This is our map of -- I'm not going to go through it, but this is our map of observed response in all these some 43 wells to the 30-day test. Most of them were no response but we got a lot of -- some data more locally. And this is just one example of calibrating to that 30-day test. That's not the best one.

So, again, we ran the model for a 22-year
dewatering period. We used drains. Stan may understand what we're talking about there. But our projected inflow is to the mine during that 22-year period was 500 to 600 gallons a minute. So almost eight to nine hundred acre-feet a year. More like nine hundred acre-feet a year.

This is a map of the mine inflows during that 22-year period so a lot of water coming in there as we got into some of those fractured features we simulated and the high storage in those fractured features.

And then we ran the predictive post mining period so we ran it for a thousand years, ran it with what's called the LAKE2 package. It actually explicitly simulates the lake and it simulates direct precipitation recharge to the lake, it simulates runoff, overland runoff into the lake that's captured in there, and it simulates groundwater inflow to the lake and simulates evaporation from the lake. So it is an explicit representation of that lake and it is balanced with the groundwater flow model that we're running predictively. But we also simulated reduction and recharge due to the existence of the tailings and waste rock.

This is the water balance for the lake. I won't go into that, just to say here is, you know, our
redline is sort of the final estimated lake inflow, 104 gallons a minute, it's about 160 acre-feet a year, and it starts to reach equilibrium in the lake and then, yeah --

So Salek had shown you these already. This is our projected drawdown 20 years after the mine. You've got the exponential plot there and you see that the mine location and we're not -- we're obviously butting up against that granite iorite here. Propagation outward after 20 years is nonexistent. We're moving outward to the east and a little bit more preferentially down Davidson Canyon.

CHRIS: Hale, the outer contour is five foot?

HALE: Yes. Five, ten, and 100.

This is what we're showing for projected drawdown at 150 years and so we began to kiss into that boundary there a little bit to the west after 150 years. As I was describing earlier, after about a hundred years we start to see a couple acre-feet a year come in. Actually, this is an outflow boundary on the west. That's precipitation recharging the mountains, and then flowing out to the west on the west side of the Santa Ritas. So we're seeing one or two acre-foot -- after 100 years, a one or two acre-foot
decrease in that outflow from the west boundary.

And preferentially starting to move downward to Davidson and moving out eastward and then this is our projections at a thousand years.

JIM: So based on your model -- this is Jim -- you're not getting into that -- the aquifer that Cienega Creek is dependent on or just peripherally?

HALE: We definitely are. Yeah, we are. This is the -- this is the basin fill aquifer that Cienega Creek is dependent on as much as 2,000 feet deep here. So we are getting into that.

JIM: Okay. I just didn't see the boundary there.

HALE: Yeah, you will see the effect here. You'll see a reduction of evapotranspiration which is the riparian area right along Cienega Creek so there is a small reduction of evapotranspiration as this drawdown propagates out.

ROGER: Hale, which layer is this?

HALE: This is water table.

SALEK: So, back to Jim's question, you know, my understanding is here's Cienega Creek proper. All of this land, the water that's underneath it and the surface is all flowing towards this. So this line here is, in essence, the reverse gradient. So instead
of it flowing --

HALE: No, no, no.

SALEK: No, no, no? That's why -- so

this is the effect -- this is the five-foot line, contour line, and the ten foot but all of this is being affected within Cienega Creek.

HALE: Right. So here is Cienega Creek here, here is the mine here, this is the -- this is the gradient. This is -- the groundwater level is a couple thousand feet higher up here than it is down here.

What we've done is we've superimposed this drawdown on this gradient. So out here maybe we've lowered it five feet, here we've maybe lowered it 100 feet, and here we've maybe lowered it 1,000 feet. So at the end of the day our new water level surface looks like that. So we still have water flowing that direction and we've got what we call a capture zone. We get a point of groundwater divide here and at some point water's actually flowing back towards the pit. But that's pretty close to the pit.

SALEK: Yeah, that's close to the pit.

VLADIMIR: Excuse me. This is Vladimir. It's easier to show on the water table map if you go to that slide.

HALE: Yeah, I don't have that.
JON: We do have the hard copy of that.

HALE: Yeah, it's certainly all in the report. Oh, I do have it. I do have it. I put it back in.

LARRY: This is Larry Cope. And what I was doing was clarifying the impact of what that cone of capture does in the upper basin to the Cienega Creek results in a slight diminishment of flow, base flow to the creek itself.

SALEK: And if we look at the scale, is this like four miles? I can't tell.

HALE: Just look at the distance of the drawdown?

SALEK: Yeah, this is four miles, this distance right here. So just --

HALE: Yeah, right.

VLADIMIR: At a thousand years.

SALEK: At a thousand years.

JEAN: And if you were to draw on the one-foot contour, how close to the creek would that come?

HALE: It wouldn't be there.

JEAN: One-foot drawdown.

HALE: Yeah. It wouldn't reach it. One of the things that happens is you reach that
evapotranspiration zone so naturally in the natural system you've got a root depth, if you would, the uptake depth. So those are different for different plant types, and so as you -- as you lower -- again, ET is the big source, the big sink in the system. So it's everything. So as you lower head slightly, you can reduce that -- capture that ET and reduce that ET and stop that drawdown if you will.

So as we -- as the drawdown reaches that ET zone, it doesn't take much to essentially buffer that drawdown, reduce that ET very slightly, and, you know, essentially stop the propagation of drawdown beyond the ET.

So the one-foot I don't even think reaches the Cienega Creek if it's less than one foot because of that buffering effect of the reduction in evapotranspiration.

JEAN: So it reaches the root zones of the riparian vegetation along the --

HALE: Right, right.

JON: This is Jon speaking, Jon Whittier. We do have a reduction of the ET there but in the report we have a graph of the projected water level in the perennial reach and it doesn't reach one foot.
HALE: Right.

TERRY: Just a time reminder. We've got about 20 minutes until they're expecting us for lunch.

HALE: Okay. Well, I'll blast ahead.

So, again, this is the model summary. We're final flow in the pit, it's a hydraulic sink. In perpetuity is what the model's demonstrating. We're not running at perpetuity but it is a hydraulic sink.

Final flow rates are 104 gallons per minute into the pit. Projected drawdown on Cienega Creek is .01 feet, if that gives you an idea. Again, that's demonstrating the effect of that buffering zone of ET. Projected drawdown at the Davidson Canyon is foot and a half. And that is where the old perennial reach used to be.

ET -- we're seeing a 1 percent decrease in Cienega Creek flow and a 17 percent decrease in Davidson Creek flow. Again, that's the perennial reach that is no longer there. ET's decreasing by about 1.5 percent.

Okay. So we've got 20 minutes. So we tried to -- you know, at the suggestion of the project team and Stan and Roger, there's been a number of different efforts to try to demonstrate that there's not a real contribution from the boundary. The last one that was put forth three weeks ago was to do a constant flux
boundary condition. And so that's what we're going to be presenting today, as well as Grady, to show as a way to demonstrate that the artificial boundary effects, if you will, are negligible in terms of affecting impacts; they're small.

And so, again, the way you do this constant flux boundary analysis, in our model we have constant head and general head boundary all around our model. Both of those are -- flow can change across them. So they will -- flow will change across them due to drawdown that occurs internal to the model. So -- in the base model, yeah.

So if you replace those variable flow boundaries with constant flow boundaries, so constant flow being the flow that is moving across the boundary in the steady state condition, the premining condition, so we can pull out -- we can get all those numbers from the model and say, you know, .5 acre-feet per year is moving across this boundary in a steady state and so we can lock all those down and then run the model again in steady state with a constant flux boundary and it will essentially look the same.

And then when you start putting a stress on the model, put a sink, the pit, or pumping for that matter, those will stay fixed. There will not be any
ability for the water -- for the flow across those boundaries to change, as Stan was describing in his thing.

So it's essentially getting to the point of showing what happens if you don't allow any changes to occur across the boundaries. So that's what this constant flux runs were for both of us.

So what we'll do is we'll compare the projected baseline general head boundary, constant head boundary projections that are in the EIS report of 2010, we'll compare that to the reports for the constant flux run, and, again, if they're similar, then it's indicating that it's not having impacts, the boundaries are not having impacts in the period of time that we're looking at. That's it.

So I did not include these in the PowerPoint presentation 'cause we were changing them -- okay. So Roger and a lot of the group have already seen these figures. Stan, I think you saw them as well. I'm zoomed in here just to give you a little bit of view but what we're seeing here is -- this is 20 years post mining and I've shown you this figure previously. And, again, we're showing the five, ten, 100, and at 20 years post mining, as we'd expect, as I've indicated, there's no change in flux. So at 20 years
post mining we're seeing identical drawdown for the
can... flux run versus the baseline run; the constant
flux run being the dashed line, which is kind of hard
to tell which is the dashed line. It's the pink line.

Then at -- this is 100 years post mining.
Same, with the exception that we're starting to get --
this is hard for you guys to see, isn't it? So with
the exception that you've got a little bit of the
constant flux drawdown starting to squib out here a
little on the western boundary. And same over here.
But in the -- in all of our areas of concern, our pink
constant flux and our blue baseline are on top of each
other.

SALEK: So that's Box Canyon?
HALE: Yeah, that's Box Canyon. So, you
know, if we assimilated Box Canyon as -- yeah, Box
Canyon.

CHRIS: Hale, I just want to clarify.
The figures you're showing us now actually have two
sets of contours on them, we just can't tell.

HALE: Yeah, right.

VLADIMIR: A dash line and a solid line.

HALE: Yeah, can you see a difference?

Okay. So this is at 300 years. Again, we're
on top of each other except for we're starting to see a
little bit more squibbing out here of the dashed line, that's the constant flux, so it's a little starved for water there, I guess if you will, causing a little bit of probation from the baseline run.

So I'd like to call this good. Once we go past 300 years post mining, we start to see some funky stuff going on and I think, you know, this is the point where I want to say I agree with everything Stan's saying, but in terms of a practical boundary, we could have sized this model well into Tucson Basin. I think that was well beyond the requirement for the scope of what we're doing here.

I do expect after three or four or five hundred years, up to a thousand years, that you're going to get some groundwater flux change across the boundaries; that's going to be expected. We're not going to design a model where you put the boundaries so far out that you get no flux. It is correct to represent that the boundary is changing flux, that's representing you're capturing some storage from, in this case, Tucson Basin; we know that's going to happen.

So, Roger, I guess the question is, is 300 years showing that these things match up and not showing any change, is that -- does that -- is that
demonstrative enough to, you know, conclude that we're --

ROGER: You're asking me for a decision right on --

HALE: Well, you had indicated the 300 years previously in the phone call so I didn't know if you had had more time to think about it.

SALEK: So map, table, graphs, we're going to talk about all those things after lunch? What some of that flux -- actually how much it is?

HALE: Yep.

SALEK: Stuff like that. So why don't we go through all of the data that you have?

HALE: Well, okay.

ROGER: I mean, the maps are nice, but data is better.

STAN: Yeah. I'd be more interested in the changes to the flow components than the maps of drawdown.

HALE: Well, I'm going to give you the maps of drawdown, too, Stan, 'cause they look really good. So this is -- and, Stan, I understand where you're coming from, in the context of the EIS, we're trying to figure out where the impacts are occurring.

STAN: Right.
HALE: And if we're causing artificially mitigating impacts as a result of our boundaries, then we definitely want to know that, but looking at things in terms of drawdown, in terms of the riparian areas, in terms of the creeks, in terms of those things, if we're not changing those things, due to our boundaries, then we've accomplished what this EIS investigation is supposed to be focused on. So I think the drawdown plots are highly relevant and the hydrographs are highly relevant and so I want to give them equal time here.

This is -- in June, we did hydrographs at 16 locations for -- at the request of the Forest Service. And this is -- this is a location map of all those hydrographs and each of those we showed drawdown over a thousand years due to the -- from the baseline model, and we also -- we did a ton of sensitivity analysis, changing aquifer parameters in the model, changing lake parameters. We did a bunch of predictive sensitivity analysis and we threw all those drawdowns on these plots as well. Those were submitted back in June. Then we added the constant flux boundary run onto these hydrographs.

So there's 16 of them. They're hard to look at. But my point is really that you can see the pink
line on here and the pink line -- I'm sorry, it's the light blue line; I've changed colors on you. The orange line is -- the orange line is the base flow run that was submitted with the EIS. The dashed blue line is the constant flux run. And the rest of these are sensitivities we ran trying to get some handle on what the variability of the model might be.

CHRIS: And, Hale, if I could just point out, the location of these hydrographs is not random. These were selected for very specific points of interest, for instance, Cienega Creek, Empire Gulch, various springs.

JEAN: Hale, it's really hard to read the X and Y. Could you read that for us?

HALE: It's zero to five feet and this is actually -- this is mining and post mining, that's 1,022 years. Sorry.

So I can just zoom through these. Basically most of them we see no change between, there's the dashed blue line up top, with the red, no change, no change, no change here. You know, again, these are at the points that people wanted us to be monitoring.

GRADY: So they can't see the scale so they don't know -- that could be -- you want me to page down while you go through?
HALE: Yeah, sure. Why don't you zoom into it.

So we're looking for the dashed blue line relative to the red line.

GRADY: Let's go back up.

HALE: None of them changed.

GRADY: Just to show that. I think you got to here.

HALE: Yeah.

GRADY: All right. So which one -- this is confluence Gardner Canyon-Cienega Creek. The sensitivity run is up there at zero.

HALE: Yeah, the baseline's the red and the dashed blue is the same.

CHRIS: Actually, Hale, could we go back to that first one to make this clear? I don't think we're getting the point across here. Yeah. This is at Empire Gulch and what we're saying is that at 1,022 years in the future the base case run had a drawdown of about 3.25 feet and when you use the constant flux along the boundaries, it was about 3.5 feet.

HALE: Right.

CHRIS: Okay, right.

HALE: And all the other sensitivities
we've done which give some idea about what the potential range is are obviously substantially larger than that variation.

So I guess we can go through each of them real quick and just say where they are. This is essentially no change at the confluence of Gardner Canyon and Cienega Creek. This is no change at the confluence of Davidson Canyon and Cienega Creek. Maybe a .02 of a foot change at the Cienega Creek gauging station.

DAN: Okay. For these no changes, you were talking about earlier the riparian influence there where basically you'd lose evapotranspiration so the water level stops dropping.

HALE: Right. So, there's a slight change in ET that's occurring, reduction in ET, so everything's within the less than 100 acre-feet reduction in ET relative to the 5,000 acre-feet a year ET that's occurring in the riparian areas.

DAN: And I guess my question is, what is the -- how did you develop the function for cutting off ET with decreasing water level?

HALE: Those are published by PAG. PAG -- Pima Association of Governments. So they've been out studying the riparian area for some 20 years, I think. And I think there's seven evapotranspiration
zones established out there which have different depths and have different evapotranspiration rates associated with them and we specifically incorporated those all into our model.

DAN: Okay. Thank you.

HALE: Okay. Cienega Creek, this is the second gauging station at Cienega Creek. I guess keep going, no change there.

CHRIS: The first one was the dam.

HALE: This one's Sonoita.

SALEK: So that's the Upper Cienega Creek.

HALE: That's the Fig Tree Spring, and I do not know where Fig Tree Spring is.

GRADY: Just north of the pit.

HALE: But our dashed blue line is overlaying the red baseline, so no change.

SALEK: This is like two miles north of the pit maybe in Sycamore Creek.

HALE: Okay.

GRADY: Up on top of the ridge there basically. On the other side of Sycamore Canyon.

VLADIMIR: Excuse me, Hale. This is Vladimir. When we review those graphs, one of those question was why some of the curves recover that are go
down and then go up.

    JON: I think if they're very close to the pit, you see that water level drop and then recover a little bit.

    HALE: That's showing pit recovery.

What is that, latest -- oh, latest arrival so that's times ten so we've increased -- it's showing response to the pit lake recovery. There's enough of a higher conductivity that we actually showed you that response more in real-time whereas there is such a lag with these that obviously there is a decline in slope rather than the actual --

    VLADIMIR: I understand that.

    HALE: I know you understand that but I'm not sure I'm explaining it very well.

    VLADIMIR: Can I ask related question and maybe you answer now or later because it was same question. You didn't mention about storage parameters which is significant. And we already start to talk about timing.

My question is, you demonstrate that pit lake elevation went to the steady state and you mentioned several times that the groundwater system did not.

Can you give us estimate what is the changes in the groundwater storage within model domain at the
1,000 years? It will give us possibility to predict when this steady state might occur. Are we close or --

HALE: No, we're not close. It's better to look at the hydrographs of the mass balance to get an idea of how that's trending, then we can look at all the numbers.

VLADIMIR: For all models?

TERRY: And can we pick up on that after lunch because it's about time we need to break. The restaurant's kind of expecting us at a certain time.

HALE: These all look the same.

TERRY: For those folks on the phone, we're breaking. It's about 12:45. We'll reconvene in an hour.

CARTER: And, you know what, actually, I have another meeting to attend from 1:00 to 2:30 so I won't be back on until about 2:30.

TERRY: Okay. Thank you very much.

(A break was taken.)

TERRY: Okay. Folks, we have three hours to get through the rest of the meeting today. We have to be out of here at 5:00.

So just really briefly, this morning Jim articulated his expectations about this meeting. My shorthand of that is the preferred outcome is to
resolve the Forest Service's concern with groundwater modeling today if we can. If not, to chart a clear path towards resolution. Okay?

ROGER: Resolution?

TERRY: Of your concerns. Is there a different word that I should use for that?

ROGER: I thought you meant resolution but I thought you said "revolution".

LARRY: Terry, when you say 5:00 o'clock, is that a hard time? Do they kick us out at 5:00?

MELISSA: I can find out.

TERRY: So, Roger, Stan, and Salek -- Roger, Stan, and Salek described their concerns with the current groundwater modeling. Hale described some of the work that he and Grady have been working on in the last few weeks in response to Forest Service concerns. This afternoon I'd like to kind of kick this off by asking Roger, Stan, and/or Salek if they could weigh in on the following couple of items, and I'm really trying to focus everything back in on what we're here to do, which is work towards resolution of the Forest Service's issues with the groundwater modeling. So if we could talk about what the Forest Service feels they need to resolve their concerns or --
and/or the specific issues that we need to talk about this afternoon that will help us work towards resolution of those concerns.

So I'm going to ask Salek, Roger, Stan, kick it off, responding to those, and then let's focus in on where we go from there.

ROGER: He said your name first, Salek.

TERRY: He's standing up.

SALEK: Well, you know, the things that we've gone over the last couple of years came -- we've come to a spot where we have concerns. Those concerns have been elevated over the last couple of months to in earnest to be able to try to start to get those numerical answers to some of those concerns, not just the verbal written portions of the boundary condition part of it, where you guys have said it should be okay. Now we're at the point of: show us the numbers, the numerical answers to some of that.

So, really, what I would like to do in the afternoon if we can actually dive into that component of it and look at those tables, charts, maps, graphs, whatever it is, whatever you guys have created over the last couple of months to kind of really show where we are on resolution of that -- of that issue. So that would be what I would be really, really interested in.
I mean, some of the stuff that Hale talked about this morning was good, some of the history. But, really, if we could really get to the meat of what we need to do today right now would be more -- it would be advantageous for me.

TERRY: Roger, Stan?

ROGER: Yeah, I'd really like to see, like Stan's capture diagrams for both the scenarios, constant general heads and with the specified flux, and be able to make some kind of decision on whether that contribution from artificial boundaries on the former is significant or not, and then go from there.

STAN: And maybe I would be interested in hearing affirmation from the Forest Service that one of the purposes, not all, but one of the purposes of the model is to look at the effect of the development of the mine site on connected features like springs, streams, and ET. If that's one of the purposes, if we want the model to do that, then I'm interested in, as Salek says, looking at the water budget components to see how well it does or doesn't do within this period of performance, 1,000 years or whatever has been agreed to. So it sounds like you guys have been working towards that.

HALE: You mean relative to the constant
STAN: Relative to whatever's going on at the pit. So, in other words, we're saying that a certain amount of water is being extracted. We want to know where that water's coming from. Is it coming from storage, is it coming from reduced ET, is it coming from reduced spring flow or discharge of streams? If that's the purpose of the model, let's discuss how the current models can do that. Can they do it? And so that's kind of what I would hope we could get into this afternoon.

TERRY: Okay.

GRADY: I think we're about to do that, right?

HALE: Stan, that's the storage numbers. So that's what's simulated in the model.

STAN: Okay. And then can you tell me what porosity would be for like the bedrock? Or just off the top of your head, is it like 1 percent or 5 percent?

HALE: You know, I would say less than -- or we've got specific yield of -- we've got 1 percent in there, so maybe a percent and a half. Specific yield --

STAN: It would be lower than the
specific yield.

VLADIMIR: Higher.

STAN: Higher. So maybe 1 1/2 percent or something like that, okay.

HALE: Yep.

SALEK: So just to add to what Stan just said earlier, this -- the models that we have now essentially are pit models. They're pit models that we're -- now the actual pit inflow, pit lake, all of those things is what the model -- the type discretization in the model was all really designed for to really answer those questions and as we start to kind of get into more distant features, that's, I think what -- does the pit model do the sensitive resources at distant locations? Does it do that part of it? And I know we could probably --

HALE: I would disagree with you probably.

SALEK: So let's --

HALE: Well, no, just on the concept that this model has very tight discretization in areas where there's a lot of hydraulic change occurring, which is what you want to do with the model so that you can minimize your numerical inaccuracies from big head changes create model instability and model error. And
just because it's larger grid cell spacing at distances away doesn't mean it's less accurate. We have a lot less change occurring out there. So the accuracy is still very defensible out there even though we've got larger grid cell space because our change in head occurring out there is very slight. So there's no -- you would not look at that and say: Gee, there's going to be a lot of model error out there because you've got a lot of grid cell space out there. That would not be correct. We calibrated this to stream flow, we calibrated it to ET. So I would say it's a reasonable model, it's not just a pit model.

SALEK: Okay.

HALE: Okay. So there's a lot to look at here. We have three hydrographs here. One is showing the actual value and, Stan, you know, we talked a little bit, we didn't overlap ours. Ours are showing above and below the zero line but they balance out. So --

GRADY: They're not a function of the pumpkin rate.

STAN: They're an actual acre-feet per year.

HALE: No, they're not a function of that rate, right.
So the first graph will be the actual values, the second graph will be the change from steady state, and the third graph will actually be subtracting the constant flux from the baseline run.

So this is the first graph, and what's really important here is we're showing both the constant flux simulation and the baseline simulation on this graph. And so, the point here again, as we were showing in the drawdown graphs and the hydrographs, we're not seeing a change in the constant flux run, which is the dashed line, compared to the baseline run, which is the solid line. We're not seeing that change.

And, again, the scale is not good to look at for these type of things, but the general point here is our dashed line and our green line for ET are almost identical. Really the only place you start seeing a change is between the blue, which is the boundary flux, you see the boundary flux change by the time you get out here is about an 80 acre-feet a year difference. So this is not a really good graph to show you details on. This is just giving you magnitudes.

So our recharge into the system is about 6,400 -- is that right? And then the largest component of outflow to the system is ET of just over 5,000. Those checkmarks stink. And then the other components of
outflow from the system are stream discharge -- whoops. Constant flux, why is that up there? ET. Right, right, right. Okay. That's stream discharge and then the other outflow to the system, this is the pit sink, and then this is your outflow from the boundary. So these are your -- essentially your outs to the system. And your change to the system is the pit inflow.

And also note here, you'll see the next graph, recharge reduced from steady state in our model due to the tailing empowerment and the waste rock empowerment footprints. So there's a little inflection here you can see, recharge reduced by about 80 acre-feet a year from the steady state condition, transient because of the footprint of the tenant. So that graph is used more for magnitude of things.

GRADY: We also have tables coming up for the water balance components at different times so you can actually see numbers.

HALE: Yeah. Okay. So this gets into a little more readable scale. This is the water balance components again but this is the change in water balance from steady state for both runs; they're both shown on this plot.

So, again, this is -- we had -- we had rates for all these components in premining, rates for ET,
rates for groundwater outflow, rates for recharge. Those were all in the equilibrium position. And then this is showing over time at any given point in time over the 1,025-year period how do those -- how is that rate different from steady state. And then we're showing that both for the constant flux run and we're showing it for the base run. The constant flux run again being the dashed.

So on the stress to the system, the sink to the system, the take from the system, we've got our pit inflow is here, which is almost a thousand acre-feet a year there during the mining, declining over time to about 162, 163 acre-feet a year.

The other stress to the system -- this is a concept that you've got to think about twice -- but the other stress to the system is from steady state. When the system was in equilibrium, we reduced recharge by approximately 80 acre-feet a year, so that's also a stress to the system that you need to essentially add to the pit inflow stress. There's two stresses occurring out here that is changing the water balance out there. It has to propagate through the system and equilibrate.

Is that all making sense?

CHRIS: Hale, the change in recharge is
a result of capture of rainfall, runoff by the immediate pit area?

HALE: Right. And capture is not a good word to use here but it is not infiltrating groundwater. It is not infiltrating groundwater as it would have been.

GRADY: Under the tailings waste rock.

JON: And in the pit, the lake.

HALE: Yeah, there's a little bit, you're right. So both of those are a stress on the system, hydraulic sink.

The capture to the system is the components of in the boundary outflow, the ET, the stream discharge; and those are the capture components, the boundary outflow, the ET, and the discharge. So the light blue line is the boundary outflow and, again, I'll show you a graph that shows you the absolute difference between these two but if you're looking at the dashed line and the light blue line, those are both the constant flux. And I apologize, this is hard to look at. You'll have to wait 'til the next graph. The light blue line is the boundary flux in the baseline run so you see an approximately 80-acre-feet-a-year change after a thousand years in the boundary flux run.

I told you 42. That was just for the western
boundary, Stan. The total is 80. Sorry.

STAN: Okay.

HALE: And then if you look at the constant flux line, the light blue line is right on zero, so there's no change in the constant flux run in the boundary flux. So this right here is that different -- actually differential, the 80 between the two runs.

The other captures that are occurring is reduction in ET, which is the green, which is hard to see. But the green we're showing a reduction in ET over time -- a reduction of a capture of evapotranspiration discharge, a slight slowing. So whatever's reducing discharge over a thousand years, and we see that change occurring over time and those two lines, the lines are almost on top of each other.

The difference in ET between the constant flux run and the baseline run, they're almost on top of each other. I'll show you in the next graph the difference is occurring.

Our last -- and then the stream discharge. Essentially, the change in stream discharge is so small it's not really even showing up on this graph. So and the other component, so your sink is equal to your capture plus your change in storage. So how much
actual water level change is occurring out there --
change in -- I guess change in the saturated volume in
the system out there is your change in storage.

So that's the last component of this, and so
you see our change in storage in the baseline run is
the light silver line here and when you put in the
constant flux boundaries, you're ultimately having more
water come out of storage. More drawdown will be
occurring because that water's not being captured, if
you will, from the outflow.

   MARK: How much was that difference?
   HALE: I'll have to look at the table
   but that's -- that should be about 80.
   STAN: So the difference in the ET
between the two runs is how much?
   HALE: Well, I'll go to the next slide.
But is this concept -- because the next slide is hard
to think about in terms of the water balance.

So are there questions on understanding the
water balance concept here in terms of what's equal to
what?

   A new thing, I guess it's been introduced,
Roger, too, you've always been talking about the pit
lake sink, the 104 gallons a minute or 168 acre-feet a
year. That's been the stress we've always been talking
about. But there's an additional stress that's being imposed on the system, which is that reduction in recharge.

ROGER: This is not the steady state scenario?

HALE: No, this is a --

ROGER: You said 104 gallons a minute.

HALE: That was at a thousand year what the pit inflow was.

ROGER: Is that what you actually have?

HALE: What's that?

ROGER: Is that what you actually calculated for the pit lake evaporation?

HALE: No. You recall that the water balance figures that we submitted with the original report that the pit lake -- the groundwater inflow to the pit is, you know, starts out at five or six hundred gallons a minute during the mining and then by the time we get to a thousand years post mining, the ground flow into the pit is about 104 gallons a minute.

ROGER: Okay. I was just throwing out the results, basically the number, which is 20,000 cubic feet per day that I used on the steady state scenario. So I thought that was somehow --

HALE: Right. Well, you asked us to use
on that steady state run -- on that June response, you asked us to use that long-term groundwater inflow for the pit for the steady state, right?

ROGER: Yeah, because to do it much higher, the steady state model would crash.

HALE: Yeah. No, this is just the transient thousand-year run that we're showing results from.

GRADY: With the higher pit influence at the start and tapering off, so it's variable. It's the full stress going on.

ROGER: Okay. So the change in storage then, what you have there at a thousand years is what, 120 acre-feet per year?

HALE: Yeah.

JON: With the constant flux.

HALE: In the constant flux. So what's not lost from the boundaries is being picked up.

VLADIMIR: This is Vladimir. I would like to point this is 120 without any run try to extrapolate to the zero. We are talking more than 10,000 years, significantly more because slope will change on the curve.

HALE: Yeah, we're certainly talking thousands of years out in the future before we reach
some type of steady state equilibrium.

GRADY: With the constant flux.

HALE: Or with the baseline.

GRADY: Or even with the baseline.

HALE: So this is trying to show you if you plug one hole, it's going to come out somewhere else. So if you turn off the boundary flux so that it's fixed, so it can't vary. If you cannot vary the boundary flux, you can't capture water that would otherwise be flowing out of the model down by the Tucson -- in the Tucson Basin. If you can't capture that, then it's going to come out of storage and it's going to come out of a reduction in evapotranspiration.

So this is your baseline change in boundary outflow. So, again, by the end of a thousand years, our boundary outflow had changed by approximately 80 acre-feet a year; it had reduced. There was a net 80-acre-feet-a-year reduction in boundary outflow after a thousand years.

So when you put in the constant flux boundary and you prevent that from happening, it wants to take it out of storage. And so this line gets a little squirrelly because we're subtracting the two storage numbers from the constant head and the constant flux run and, at this level of accuracy, it's jumping around
a little bit given how small this change is relative to the overall mass balance of the model.

And the other component here is evapotranspiration is increasing -- I'm sorry, decreasing. So we're capturing some ET and we're taking more water out of storage. We're dewatering more to offset that water that we couldn't take out of the boundaries, we couldn't capture from the boundary outflow.

So, I guess I want to -- I want to get back to this graph before we go to the table, but I think it's really important here, conceptually everything we've been presented as far as concerns about the boundary conditions, that's all correct, but what we're looking at here is a time issue and when do the boundary effects even begin to come into play? And, then again, at a thousand years, how much are they a component of the change in the system?

So we don't even see boundary effects start showing -- we don't even see any impact on the projections until 100 -- almost 100 years, you know, 80 years after end of mining. And, as I showed you in the drawdown graphs and in the hydrographs, you know, this is the change, a little bit of change in storage and a little bit of change in the boundary there.
Those don't manifest themselves in terms of drawdown even at 300 years. The change in head, the drawdown that's occurring in the system, the concern we have about how the pit is going to be impacting the system, those don't manifest themselves until well beyond 300 years. I can show you graphs out to four or five hundred for hydrographs -- I mean, for drawdowns. And it's not changing. The system is large and it's robust and this translates to almost no changes.

I mean, this change in the boundary, if we made that go away and we took it more out of storage, took it out of storage exclusively and reduced ET a little bit, that doesn't affect the drawdown projections for the model in a thousand years. And you can see it in the drawdown plots where they compare identically to the baseline run and you can see it in the hydrographs where you compare it to the baseline run.

And, you know, that's the -- I think in my mind that's what we're trying to determine here is do the boundaries cause any change in the drawdown impacts to the system or the reduction in anything that's in areas of sensitivity, you know, hydrographs drawdown in the areas of sensitivity? And what we're seeing is no. And the point there is -- and in the previous
memos we've sent to the Forest Service I think we were just showing what the numbers were. I think we were trying to say we're not reducing, we're not -- overwhelming amounts of water aren't flowing in our boundaries. We were giving you tables and numbers and you could add them up and you could see they weren't that much. But we haven't -- I guess we should have gone to the graphics earlier and shown you that the differences in the drawdown is negligible.

And I think, getting back to the EIS process, I think that's what we're wanting to look at is how much is that drawdown changing and -- because the boundaries after a thousand years aren't giving us that much water, then the drawdowns aren't being affected by it.

So, I need to switch. This table was -- we went through a bunch of different ways to show this and we revised this again this morning and so I apologize it's not got all the headers on it.

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ROGER: Can you zoom that?

HALE: Yes.

TERRY: Did somebody join us on the phone?

CARTER: This is Carter Jessop.

HALE: So we did snapshots and we tried
to break the components out in a way that would make sense with the graphs we've shown you.

The first block here is at 20 years and Column B is the net number for recharge in this case in absolute. I'm sorry. Column B is the baseline run and Column E is the constant flux run. And then we're showing the net components change for recharge stream.

Constant head and general head boundary, those are added together to get Line 8, which is the net BC -- this was meant to be in italics -- these, six and seven, add up to eight.

Boundary condition, net boundary condition change.

ET change, the lake, and then the change in storage.

So this may mean most to Stan. And in 20 years post mining, we're not seeing any change because we haven't actually even had any boundary impacts at all. We're not reaching the boundaries with our drawdown. We would not expect to see any change at 20 years post mining. So these numbers, the differentials, are zero there.

SALEK: We're still in a waterfall condition, right, in essence?

HALE: 20 years post mining? So, well,
we're always in that condition where we've got a sink towards the pit.

SALEK: It just hasn't propagated down?

HALE: That drawdown has not propagated. It's not diffused through the western bedrock boundary. It hasn't reached, you know, all the way up into Tucson Basin north of the Empiritas. So we get to 100 years and, again, B is the baseline, E is the constant flux run, recharge of course is not changing. The stream is starting to change slightly between the two runs. The combined boundary effect, you're showing that after 100 years this is basically telling us that we were picking up five acre-feet a year from the boundaries in the baseline run. That was the contribution to the model from the boundaries at the end of -- at 100 years from the baseline run.

So we took that away in the constant flux so that's why you get a different show of five there. ET, to reflect that drop to one acre-foot a year. And under storage, coming from from storage increased or -- well, increased by minus eight.

So these numbers are -- there's some rounding stuff here -- this adds up to seven, Stan, as you can see, instead of eight. But trying to fit all this into
these really small numbers was really problematic.

And then down here at 300 years, we see -- again comparing B to E, we see a two differential for the stream. We start to see the change. The contribution of the boundaries are obviously higher now in the Column B baseline run relative to the Column E constant flux run. And we pick up -- we pick up 28 acre-feet a year here from storage now.

And then this is at -- that's interesting. This is at a thousand years. And one of the things to mention here, our -- Jon, this is comparing at 950 or a thousand years?

JON: It's a thousand. And 950 was the farthest we could go. So -- it's comparing the ends of the simulations.

HALE: They could be slightly off. So our -- okay. Our constant flux run, basically we failed to converge it with --

JON: 960 years.

HALE: -- 960 years it had gotten stable. Again, we were out there in the bleeding edge of this thing, and at 960 years. So this is actually comparing 960 years, not 950, to 1,000.

JON: No, 950.

HALE: Oh, 950. So our differential is,
again, recharge, one, I can't explain that actually.
The stream difference was an acre-foot a year change; a
boundary difference at 950, I guess, was 77, which
should, I guess, get up to 82 or 80 or at a thousand,
right, Jon?

JON: I would think so. It looks like
the storage number is off.

SALEK: Yeah, 'cause it's a lot less
than it was before. It should be a lot more, right?

JON: I'm not sure. Copy the formula
down from the 77.

HALE: It's on the 77? Nope. Is that
right?

JIM: The percentage didn't change. The
percentage formula is not --

HALE: I'm not sure really what that is,
gentlemen. 168 -- 50 -- divided by B, 40. Yeah, so,
okay, I guess that makes sense when you think about it.

So, you know, this is our net effect to the
mass balance components of the flow system after really
950 years 'cause our constant flux wouldn't go out to a
thousand; we could not get it to converge without --

SALEK: Could you scroll up just a
minute? What was that one before? That was 300?

HALE: That was 300.
SALEK: So 13 and 13 percent?

HALE: Yeah, and that's just a change relative to itself.

SALEK: Mm-hmm, right.

HALE: It gets complicated here. I guess we're trying to quantify this stuff that's been showing those figures, but it keeps going back to these are small changes that are occurring here relative to the mass balance in the flow system. And that's manifested itself. When you compare the two runs, it results in the drawdowns are not changing in the areas of concern and over the thousand year period that we're evaluating this. That's all I've got.

SALEK: So the net boundary on this one, Line 47, is -- 77 is the difference, right?

HALE: Yep.

SALEK: F 47?

HALE: Yep.

SALEK: 77 acre-feet per year?

HALE: Yeah. And that's really showing, again, we're comparing a 950 year to a thousand so that really should be about 80.

SALEK: Okay.

HALE: But, again, the quantity here --

SALEK: It would be about 50 gallons a
HALE: Yeah, 40. Yeah, in our -- I'm not too keen on the whole mass balance numbers for the constant flux. It's probably more useful for looking at the baseline constant flux numbers, the baseline mass balance numbers.

And what we've already demonstrated and talked about is our boundaries -- you know, the point of this meeting, our boundaries are giving us 80 acre-feet a year. We're -- in the baseline model, the boundaries are being reduced by 80 acre-feet a year, the outflow after a thousand years. So that 80 acre-feet a year is, you know, conceptually mitigating the impacts, mitigating the drawdown.

But the point I'm trying to make here with the drawdown graphs and the hydrographs is that's not changing anything in terms of impacts on the flow system. It's such a small amount that it is not changing things after a thousand years. And --

SALEK: But on a system that's dewatering 104, right?

HALE: Well, on a system that's dewatering, you know, whatever, 160 acre-feet a year, plus -- this is important and it's a hard concept to get. We're also creating -- you know, reducing
recharge 'cause of the tailing and the waste rock right at -- that's like putting a well in at 80 acre-feet a year. So those two combined components are the two stresses on the system. And adjusting for that to ultimately give back and make delivery a thousand years down the road, that water's going to have to come from either ET reduction, ET discharge reduction, or in our model from a reduction boundary outflow. So it's getting there, but it's certainly not there yet. We've got thousands of years to go before we get there.

STAN: And what I see happening is the original run had -- you were constraining the heads at the boundary, not allowing it to move or much. You had a GHB, general head boundary, and now you've gotten rid of those. So you're allowing -- head is no longer constrained so you have -- it's going to take more time on this second run to reach equilibrium than it would have on the first run. So I think that 80 acre-feet per year of capture from artificial boundaries, you're kind of seeing that in the storage change term.

HALE: Mm-hmm.

STAN: Of course, if you were to look further out in time, that would be more manifest in ET and springs and things like that. But evidently not in
this period. And if you had a model that had a larger
domain, like you went more to the south and more to the
west or to the east, it would even take longer to come
to equilibrium because those storage changes would be
able to propagate out into those other areas, so you'd
be looking at even longer times to reach that
equilibrium.

VLADIMIR: This is so.

STAN: So -- but what we're seeing in
this period is we're switching that change in boundary
flux that they got from their original model into a
storage change, and so that may not -- it evidently
doesn't translate to great differences in drawdown;
80 acre-feet over this very large area could be very
small changes in drawdown.

LARRY: And, Stan, just a point of what
you just said. The graphs that Hale showed right
before lunch kind of confirmed what you just said
because between the two different --

STAN: The contours?

LARRY: The time graphs showing the
differences in drawdown over time were very slight. So
that that's all borne out in the data, though -- though
the model is, you know -- has points that can be argued
and there are points that it doesn't fit the robust,
perhaps intellectual, formalization that it could stand -- formulation it could stand.

Within the bounds of the EIS impacts analysis and within practical considerations of what constitutes an impact of feet to drawdown, it seems that this model, in my view, is applicable in a practical sense. In the context of the EIS, it impacts the analysis.

There is always an intellectual endpoint. There is also always infinity. There's always -- you can go as far as you want but in terms of what really -- what happens practically, I think they've demonstrated -- in my mind they've demonstrated today that the model can be used to assess impacts from a practical standpoint. That's just where I stand on it at this point.

Oh, by the way, something else I wanted to mention and that is I think everybody here understands why SRK is here and -- but let me fill that in a little bit. We were asked some three years ago at the very start of the modeling exercise to support the Forest Service. We were hired by the Forest Service to support them and advise and render opinions and work with the modelers in developing the models. So it started right from the very beginning with conceptualization and the building of the conceptual
model, right through the geometry and these iterative steps of dealing with the issues that have come up, the boundary issues, the moving of the western boundary early on, and then these iterative steps of testing the boundaries and the veracity of the boundaries or the applicability of the boundaries.

So this is a process that's been going on for three years in which these questions have come up, they've been worked on, they've been demonstrated and resolved or not, and we're left today at this point coming to a point where we need to close or, as it was stated early on, know how to close.

So we have to -- in the next two hours we have to write down where we agree and what we need to do to get to agreement. That's my two cents' worth.

CHRIS: So, Larry, let me ask you something to clarify. When you say practical applicability, it seems like there's a time component there 'cause I think we can all see from the graphs that 100 years out there's no change, there's no influence of the boundaries; 300 years out there is some; 1,000 years out there's more.

So does the practical applicability have a time component?

LARRY: Another two cents' worth might
be that there is a band of uncertainty, let's call it noise. There's a band of -- for instance, an example of that band is the fact that over the last five years the upper stretches of the Davidson Canyon have not flowed. Does that represent something that's outside of expected? Does it represent a change in the system? Does it represent an imbalance? Maybe it's simply part of the noise of the system, the natural variability of the system.

So, to me, the context for timing is at what point does uncertainty get lost -- does uncertainty grow, whether it's development of additional use of water resources in the basin, climatic change? At what point does that band grow so large that it swamps the variability of the bracketing of the potential impacts that we're trying to look at?

So the question is: How far out is that point? We can go five years, because the upper reaches of Davidson have dried in the last five years. Does that represent an aberration or simply a natural fluctuation in some band of uncertainty? Or we could go out a thousand years or more.

CORI: Or a million.

LARRY: Or a million. But at some point the science is swamped, our ability to predict is
swamped by the broadening of the range of uncertainty as we move out. It's like this --

VLADIMIR: If it's possible, I would like to add to Larry and we concentrated on the boundary condition. Why? Because it's not symmetrical model and first what we can see is pit is here, boundary is here. I think that there are more uncertainty exist in this model than boundary condition, even more uncertainty than boundary condition, because it's very large area. There is not any possibility to characterize each point of the consultant hydrogeology.

What was done by author of these two models, it's prepared extremely large range of the sensitivity analysis, and if you will compare their sensitivity analysis, say, on the hydrological parameters, they are creating even larger range of the changes in the drawdown than those boundary conditions.

I'm trying to say that this is not absolute precise -- precise prediction, too. But it's still one of the best tools which is available right now in the sense to predict potential changes in the water levels and associated impact.

And I think in our opinion, again, some uncertainty is still there and more uncertainty in my
opinion in the parameter, in the storage parameter, but
those uncertainties were covered by this sensitivity
analysis with possible ranges of the impact.

Maybe I'm wrong but it's more than
30 different wells by weighing different parameters of
groundwater and surface water systems were completed.
If impact to critical areas within this range of the
parameters is acceptable, it means this model is
acceptable for the purpose of the prediction of this
impact. You do not have -- unfortunately, you do not
have any other tool to predict this, which is why I
raise several questions about timing question.

Model is extrapolation, extrapolation your
knowledge from the past to the future. How far you can
extrapolate? And I'm in the groundwater modeling
business, modeling 25 years. I can tell you I wouldn't
trust any prediction by a model which I developed more
than 1,000 years.

CORI: You'd want to calibrate it on a
regular basis.

VLADIMIR: To predict 1,000 years I need
to calibrate the model at least to the 50 years of the
stress.

LARRY: And this is what you drove at
earlier when you talked about how the model grows as
you recalibrate. As the pit grows, you get the new
data, you're able to refine the model but only through
the scale of that operating mine. That's what really
lends itself to the better predictions down the road.

CHRIS: I just thought this might be the
perfect time to jump back to the bullet points that we
tried to boil down because I -- at least I think I'm
hearing agreement on the basic issue that you need to
look at boundaries, right? I mean, that's kind of what
Stan was demonstrating and what Roger said. I mean,
there's no question on that front. I think I hear
agreement on that. And we've looked at those and we
now have a pile of evidence to weigh on what that
means.

TERRY: And so is that true, that we
have agreement on that point?

STAN: That we need to look at
boundaries?

TERRY: Exactly.

CHRIS: But I keep coming back to --
which is why I asked the question of Larry, you know,
timing is critical. I mean, that was one of the things
we wrote down, and I heard it several times, and it
also kind of ties in with Roger's statement about
steady state.
So I guess that deserves a discussion because I come back to the numbers that we've seen that have been presented are pretty clear-cut for the first couple hundred years. I mean, we can argue percentages and what we're comparing against but there really just isn't any impact until you start to hit the 200-, 300-year time frame. So it just seems like that's kind of the key here is --

MELISSA: Does everybody agree with that? I mean, does everybody agree that they're not seeing a huge effect past --

JIM: What I'm seeing is even at a thousand years, even though it's a percentage difference, that what I'm hearing from Hale was that even at that percentage, it doesn't have a significant impact on the actual drawdown. Is that what I heard?

HALE: (Hale nodded.)

STAN: I could say a few things about timing.

With the model domain that you have, I don't see these models being able to predict the timing of impact of the withdrawal at the mine on ET or springs or streams because either way you do it, with the constant head or constant flux boundaries, you're doing something artificial. So the actual timing is probably
longer than you're predicting here.

So what your test suggests is that the major impacts are going to occur after a thousand years because you're seeing all the changes being shifted to storage, and if you had a real model domain that was larger, you'd even have a longer --

CORI: A real model?

STAN: Well, real versus artificial, right?

SALEK: Yeah, real versus artificial.

JIM: He wasn't trying to characterize it.

STAN: Well, I had real boundaries and artificial boundaries. So it would be even longer.

So I think what you're suggesting with your model is that you're not looking at the timing of the effect on ET but you're suggesting that it's going to be further in the future. By changing these boundaries you're getting more storage change out of the thousand years where the big difference was that that boundary flux you had before that you were capturing is being transferred into storage change but if you -- if you were to look at a longer time frame, what that -- you had in that 80 acre-feet from the boundary flux, that would be a change in ET and spring flow and stream flow
'cause storage change is eventually going to go back to zero.

So I'm wondering if there is some merit to looking at steady state. And you might look at it from this point, that if you have 160 acre-feet of water being taken out of the system and you have thousands of acre-feet or ET -- how many thousand, Hale?

HALE: It's 5,000.

STAN: 5,000. So really the most effect you can have on ET in steady state is 160 acre-feet, right? Why not tell people that? Or tell them that this much of it -- we're not sure of the timing but we know that -- we think that possibly this much is through ET change and this much is from spring flow change. I mean, that's not necessarily --

JON: Well, in looking at the boundary flux, I do think -- we think that there's going to be a reduction in outflow from Davidson, from Cienega to Tucson Basin. So that is a viable thing. We are going to be capturing some water that would flow into the Tucson Basin. So there are three components --

STAN: But that's really not calculable because you've got a continuous flow system, right? The only really thing you could --

VLADIMIR: It's a reduction.
STAN: But that's an artificial boundary.

JON: No, but even if you project -- if we simulated all of Tucson Basin --

STAN: Right.

JON: -- we would have a reduction of water from one basin to another.

STAN: You would have a reduction of water -- if Tucson Basin had flowing surface water that you'd capture, then you would -- I would buy that.

JON: But then we're going all the way to the Colorado River.

STAN: No, you're not because you're capturing whatever you have in this vicinity, which would be, you know, Cienega Creek and ET. So you'd be -- all of it would come from there.

GRADY: That's the only surface water bodies to capture it from.

HALE: We're a little dry.

STAN: So the fact that you have an artificial boundary that represents flow from this area to Tucson, I mean, there's no surface water, nothing beyond there that could be captured and there would be no -- in steady state, you know, the storage change out there would be zero like it would be everywhere else.
So really you have to look at perhaps you have the San Pedro River or maybe in between there there are some springs.

HALE: Right.

STAN: But --

HALE: That's literally thousands and thousands of years in the future obviously and your comment, just come clean and say at the end of the day, 10,000 years down the road you're going to reduce your ET by 160 acre-feet a year.

MARK: That saves a lot of time.

HALE: So, you now, we can say that and that will be a 3 percent --

STAN: You might want to show people that we're going to reduce, you know, and most of that is going to be from ET, a little bit from this perennial reach or this spring or something like that, not that the models are maybe not very good for dividing that up either because the artificial boundaries may have some influence on which features are being affected.

HALE: Well, I think they don't have that much effect after a thousand years, Stan. It's not really reaching the boundaries.

STAN: But I'm talking about ultimate
effects.

HALE: Yeah, and I just can't think that way. A thousand years to me is the extreme ultimate consideration for this model. Going beyond that and putting anything out there in steady state is, I think, wrong in terms of any defensible results.

STAN: It's actually probably more defensible than what you're doing because what you're doing is trying to predict things through time, you know, timing, but the steady state, that's just a simple mass of balance. And you would not predict a thousand years on a, you know, 30-day pump test, but based on mass balance and conservation of mass, I would predict that if I pump a well here, you know, at a certain rate, and we have these certain connective surface water --

HALE: You would definitely be right, we just don't know when.

STAN: Right, you don't know when. And why don't you tell people that?

MARK: But would you agree it's likely to be much, much larger than a thousand years?

STAN: It seems to be from what Hale's presenting. I'm kind of getting that from your bounding. But I don't think that either of the models
could be used to accurately predict the time of,
saying, changes in ET.

GRADY: So we're getting to the
magnitude of that. It's 104 gallons a minute in the
Montgomery model, 230 gallons a minute in Tetra Tech
model. So that's going to be the steady state capture
for that entire area out there. So putting that in
context of what the impact of that is what we're
saying, so --

STAN: Right. I don't -- what I'm not
sure about is that -- there's a whole bunch of water
loss in the system early on, you know, filling the pit
lake and how that has to propagate. The steady state
model wouldn't address that.

HALE: Right.

STAN: It would just address that very
long-term loss.

GRADY: Right, right. Yeah, lots going
on there in the earlier times there.

JEAN: That, again, assumes that the
transmissivity values are accurate. I know you guys
had a whole separate discussion apparently on karst
topography. That is another assumption that needs to
be considered.

And, Stan, you had talked about the
possibility of maybe modeling drawdown directly. You want to talk a little bit about that?

STAN: Well, if you did want to do a model that had a larger domain, I think you could do it with a change model, that, you know, you could flatten out your model and just represent the exact transmissivity you have in your model domain and then add transmissive blocks on each side that were representative of the material that you have. It wouldn't be characterized to the degree that it is -- well, to the west you could add it -- you could get data from the Tucson Basin model and use the storage properties and then compute drawdown in what's called a change or a super position model. You could compute it directly and you wouldn't have the, you know, the problem with that boundary and effect of that.

And I should point out it's not just that west boundary because it looks like half of that boundary, artificial boundary, captures from the west boundary and half of it is from all other boundaries. That would be something that would probably be done in a matter of weeks or few months and not years.

HALE: Some from the south.

STAN: Super position model, translating your model into that kind of a model.
MARK: Stan, would you agree that the -- that the worst possible outcome in terms of capture of ET would be 160 acre-feet per year of capture, and that the model, if we did what you're suggesting, could not -- that that would be the largest impact?

STAN: Yeah, I mean, if you believe -- Hale, does that include the reduced ET from the pit or is that in addition?

JON: The reduced recharge?

STAN: Yeah.

JON: The combined is 240.

HALE: Stan, I come back to the points you were making about you think we're changing -- you think we're artificially affecting the arrival of the -- the occurrence of the ET reduction. I guess for that --

STAN: I think you're actually -- yeah.

HALE: Yeah, go ahead, sorry.

STAN: You're actually predicting it faster than it should occur.

HALE: Okay.

STAN: Because if you had a larger domain, you'd have storage changes that would propagate out into that. So it actually would probably take longer for the effects to reach the ET areas.
MARK: Even the first 300 years?

STAN: Yeah, it could slow that down.

MARK: So the drawdown and ET were virtually identical with the constant flux versus the general head boundaries so it seems like --

STAN: It could be the same there, yeah. In that range, it could be the same, right.

MARK: And then once you go out further in time --

STAN: Right.

MARK: -- then it gets -- some of these questions become more relevant.

STAN: Right, right.

HALE: I'm just trying to -- on my screen right now is a blowup -- so the concept of -- you know, Stan, I agree conceptually that actually maybe what we're showing is conservative but with or without the constant flux boundary, the dashed line and the solid line are ET. And so that inflection for both are occurring pretty much at the same time with the constant flux.

STAN: Right. What I'm saying is, see your two top curves? Those are your storage change curves.

HALE: Yep, yep.
STAN: And that 80 acre-feet difference in your two storage curves is eventually going to be an 80 acre-feet difference in ET.

HALE: Right.

STAN: Right now you're showing no difference in ET but if you were to look further out, that's where that 80 acre-feet is going to go is into the ET.

MARK: Let me talk about that a little bit. That, you know, if we had a very extensive model, that during a thousand years there were absolutely no boundary effects, then wouldn't it predict something in between those two lines for storage if you showed flux at the current location of the boundaries?

VLADIMIR: Yes.

HALE: If you were picking something else up.

STAN: Well, it could do all kinds of things through time but if you run it long enough, that storage change is going to go to zero.

MARK: Yeah. But it would be the upper dashed black line and the light gray line just below that, those -- one is constant flux, one is the general head boundary. If you had an extensive model, and you calculated flux at that same location, wouldn't it be
somewhere between those two lines? Wouldn't it have to be because constant flux is --

STAN: This is actually global storage.

HALE: In a transient sense it would.

MARK: So I guess my only point being that some of that 80 acre-foot difference would still come out of storage if you had a very extensive model.

STAN: At some point in time it would but not at steady state. At steady state it's all going to be coming out of ET.

HALE: But at this point in time you would be halfway between there.

MARK: Right, right.

STAN: So both of those two curves are headed to zero, they just haven't got there in a thousand years.

HALE: In terms of the impact consideration, I guess what I was getting at, I agree conceptually that we may be conceptually showing impacts earlier, if you would. And that means we're conservative in terms of the EIS analysis. And I'm also just saying that, you know, as far as the onset of the effect of the boundary condition, the constant flux boundary condition, compared to the baseline, they're both showing that inflection pretty much
simultaneously.

So, again, I think the effect of the boundary on this overall -- relative to this overall system is so small that it's conceptually -- I agree with what you're saying but it's not -- it's not having a real dramatic impact, I think, on things.

STAN: What I'm saying is why not tell people what the ultimate long-term effect is? That's actually more defensible than the timing of the effect that's influenced by a lot of different things in your model.

MARK: When you say a thousand years, though, we do have some confidence --

STAN: Actually, I have more confidence that if you have 160 acre-feet being removed, or 240, I have confidence that if that went on and on and on long enough, you would have that much reduction in outflow.

HALE: But the EIS process --

STAN: You don't need a model for that.

HALE: You're right.

VLADIMIR: Add this amount to the --

HALE: We need to know when, and that's the whole timing issue here.

STAN: Well, I think you can make an argument from which you've done that, it's out in time.
HALE: Yeah.

STAN: That it's -- in a thousand years you're still seeing storage change and it would be even longer if you had a larger domain. So that's kind of a line of reasoning I think you could use.

SALEK: So that's actually something that we could write up, SWCA, in the documents without actually getting that actual wording from Montgomery and Tetra Tech potentially.

VLADIMIR: You could take from this graph.

SALEK: That's what I mean --

VLADIMIR: If it's possible, I would like to say a few words.

Two models during 1,000 years constant head and constant flux. Constant flux there most conservative model, constant head least conservative model. Most likely it's something in between, right? We can take the difference in -- we can take average rate of the changes, changes in the groundwater storage and the prediction, and assume that something between finally in thousand years would be applied to the reduction in ET. And, in my opinion, you could deal with the big model.

If you build the big model for first 1,000
years, most likely you will receive exactly the same result. You need to use bigger model to predict what will happen beyond this period of time. But isn't any need to do this. Just assume that this storage, which something average between constant flux and constant head, among the boundary conditions finally will apply as reduction in outflow and you could put this probably in EIS in the section which would describe extension of the prediction beyond the 1,000 years.

LARRY: Let me ask the question. I'm sorry. Let me ask the question: How does this discussion, how do these differences affect how Jim makes his decision? What does this -- what does this mean in practice to us? We are talking about some technical differences, we're talking about some approach differences, numerical differences, but what does it really mean as far as effectively where we go from here with the decision? Help Jim make this decision.

JEAN: Speaking for Fish and Wildlife Service, I know we have to consider what the worst-case scenario is and there are some uncertainties in it. So being able to understand what the worst-case scenario is, where the ET is going to be pulled from. So does the model accurately reflect which reaches and which
streams are going to be ultimately impacted and how much impact there's going to show up at those streams? And did the model consider that Davidson Canyon was still flowing or did the model consider that it is no longer perennial?

JON: We considered that it was flowing.

JEAN: That it was still flowing. So it's no longer perennial so actually, that would --

LARRY: It's just the upper stretches that are not perennial. The lower stretches are still ephemeral.

JEAN: Right, right. So does that mean if it were considered --

JON: There was some impact to the stream but it was -- the ET was more of an impact.

JEAN: So there would be more impact further downstream considering the current conditions.

JON: Right, right.

JEAN: I mean, those are the kinds of things that would be helpful for us in making our decision.

DAN: I think tied to that, too, is, as Hale was saying, the model basically is drawdown showing that it would transfer that to ET, changes in ET. Basically, some plants' water level would drop
below the root depth and those plants would wink out; therefore, no longer pulling water. I think maybe in the body of the EIS we need to bring that forward and say what are the expected changes in those plant communities. So basically we are -- I know it's not the groundwater side effects, but basically taking that groundwater side and bringing it to impacts to riparian communities, what species drop out, what species stay, what species may come in because of that. You know, do we lose one species and pick up tamarisk, salt cedar.

So basically what are the changes in the community as shown by, what did you say, PAG, the association of government zones, the zones they came up with? They obviously had some plants in mind when they developed them so what are the shifts we're seeing based on these modeled results, what's the expected change in that vegetation community?

Now that's one not for the groundwater side.

That comes back over to the EIS.

JIM: It feeds into the analysis, the groundwater numbers. So when you say what does Jim need? Jim needs to understand what the effects are on the resources that we're concerned about. So if you are showing me and you can demonstrate, based on the worst-case scenario or the best case scenario, that
these are the range of effects, that's what I need.
And if these additional stress analyses or sensitivity
analyses that you've done can show that it can
accurately predict that as much as humanly possible,
then that's what I need.

And so what I need from this is that we're
confident that the additional information that has been
done by Montgomery & Associates is sufficient to help
us to make that prediction.

TERRY: If I may step out of my role for
a second. From a NEPA standpoint, I think it's fine,
it's all about disclosure, right? So if we're able to
predict effects that far in the future, that's fine.
But what goes along with that is a discussion of
uncertainty, which we're spending a lot of time trying
to do in this particular EIS because there's a lot of
uncertainty associated with a lot of modeling. And so
we can certainly describe those effects but we have to
put them in the context of, as I think Larry pointed
out, you know, whether they get lost in the overall
noise of the natural variability or not. And we don't
have to peg that as a specific time, but we do need to
have that discussion.

MELISSA: What I'm thinking, and
particularly where Fish and Wildlife is concerned,
you're discussing the worst-case scenario, and I know a lot of the waters that you guys are concerned about are Davidson, Cienega Creek, based on the species that are located there. And one of the other discussions that we had at the May meeting was the difference between those waters and whether or not effects to those waters can actually even be guesstimated by utilizing these groundwater models.

And so although we're -- so I know we're talking in the modeling realm of the evapotranspiration and the riparian areas and things like that, but I think there are other contributing pieces besides just this groundwater model or the models that feed into the impacts into those areas that -- so I -- while today we're focusing on the modeling efforts and trying to make sure that people understand, you know, and are comfortable with boundaries that are used and there's, you know, some reasonable consensus as to making sure that this tool is appropriate for what it's looking at, for the big picture effects, when we're talking about Davidson Canyon, Cienega Creek, there are other contributing factors that may or may not lead to valid impact statement. A little different than this conversation, I think, at this time.

CHRIS: Maybe I can expand on that
because I had the unenviable task of translating all of
this modeling to impacts assessment in the EIS. So at
the May meeting -- well, let's take one model
prediction.

Cienega Creek, the model does predict a -- if
you look at average flow it's a 1 percent reduction in
average flow in Cienega Creek. I think, Hale, that's
what it was. That reduction in stream flow is driven
by less than a 10th of a foot of drawdown. We're
talking a centimeter drawdown.

At the May meeting, we had a pretty long
discussion about mathematically, yes, absolutely it
shows a mathematical change out there. But what I
heard was that, you know what, the professionals look
at these models and they think anything less than five
feet you can't rely on.

So when I took -- these are just tools. These
are one of the tools we have to assess impacts. So
when I had to decide and try to create an impacts
analysis for Cienega Creek, I had to ask myself, the
models may say 1 percent reduction in stream flow. Can
we use that? And I came to the conclusion after our
last meeting that, no, we cannot use that in good faith
as a realistic prediction of what could occur in
Cienega Creek.
So the impacts analysis is much more qualitative. It's informed by the models, don't get me wrong. The models do demonstrate that a reduction in or a drawdown in groundwater could occur at Cienega Creek a long time in the future, very small levels. But that's a qualitative assessment. I did not -- after our last discussion I wasn't able to take those models as gospel and carry them forward into the impacts analysis.

So when we get to what does this mean to -- can we use these models and what do they mean to our actual EIS analysis, you know, the actual EIS analysis is much more qualitative. It's informed by the models but it does not rely solely on the models. Five-foot drawdown -- those five-foot drawdown contours, that's pretty much the extent of what we felt we could believe, what we could rely on.

So, you know, the question of whether we can take the predictions of ET reduction and use those -- now, we did -- we did do a much more extensive analysis of riparian areas but they weren't based on ET reductions coming from the models. Because those are based on such a small drawdown, it's a mathematical fiction. We did not feel that it represented a reality that we could really use.
So it's -- I know that's very strange because we've been talking about these models and we want to rely on them and I totally agree but I also have to put them in the context of how I actually used them, and it's -- they weren't used at that level of accuracy, I should say.

JIM: Or a specific reach or something like that or a specific spring?

CHRIS: Right.

ROGER: The best use is looking at the overall mass balance because you know that if you're evaporating, say, 200 acre-feet per year, that's ultimately going to be balanced by 200 acre-feet per year of loss in stream flow and evapotranspiration and, I mean, basically that's the bottom line, what's the footprint of the area where that loss will occur is.

HALE: And, really, it buffers up against that ET area and that's pretty much where most of it's going to go. That's going to be the extent. And you're talking ultimately -- you know, Grady uses this ARM model that's 240 acre-feet a year. Some of it's going to be lost other places, Davidson and the stream flow, but most of it's going to be lost to ET 10,000 years in the future, and that's going to be relative to the 5,200 acre-feet a year that's the
baseline ET discharge. So -- half a percent; is that right?

CHRIS: What's that?

HALE: 250 divided by 5,000? Reduction.

CHRIS: So what Salek said earlier, which was maybe we could write that into the EIS, that fits with what we've done. It would be using another modeling technique or using another model run to inform this more qualitative assessment.

The question I would have is can we take -- can we take that tool, say it's a steady state run, can we correctly apportion it? Can we say: This much of that water loss will come from ET, this much will come from reduced stream flow? That's the question I have. Can we construct a steady state model that could correctly tell us this will reduce -- be from capture of recharge that otherwise would have flowed into Tucson Basin?

HALE: The answer to that is no, because that's 10,000 years out. We don't have a 10,000-year model that's going to be accurate for that. So I would not hang my hat on that. I agree with Stan. We know ultimately that's what the breakdown will be, but we can't give you a model that's going to predict when that's going to occur 10,000 years out, which really is
what we're talking about.

STAN: But you're not predicting when it's going to occur.

HALE: We need to for the EIS. We don't want to say this will happen for the EIS period analysis, 'cause it won't. It will happen 10,000 years from now. The EIS period analysis needs to give an idea of what would happen.

STAN: So you want to run it to a steady state not do a steady state run directly?

VLADIMIR: The question is will you believe in this distribution which you will receive? You will receive impact or reductions in stream flow, ET, maybe some other components. Will this steady state model will give you exact, I believe it would, but will you believe in this reduction in this distribution from different sources?

STAN: I'm not convinced that the artificial boundaries would not affect that distribution. I think it's possible that they would.

VLADIMIR: If you take big model and predict steady state prediction that will occur in 10,000, will you believe this?

STAN: Yeah. I mean, in one case you have the steady state model, it would have to be the
one with the constant flux boundaries, and compare that
to the results of a model with a bigger domain. It's
possible that that -- the drawdown reflecting off of
these -- the edges of this rectangle could affect which
particular features are being affected more than
others.

And the fact that you don't have this high
transmissive zone off to the west, you know, and the
valley fills, all those things could possibly affect
which features would be affected. But doing that with
that steady state run, you know, as you've done with
the constant flux boundaries, just run the steady state
would be better than nothing, I think.

GRADY: Just run the transient model
'til it approximates steady state?

STAN: Either that or just -- I mean --
I guess if you have to say when steady state's going to
happen, maybe you have to do that.

HALE: Well, we don't have to say when
steady state's going to happen. That's the hang-up.
We don't -- if we're --

STAN: I think it's informative to tell
people that at steady state, you know, we have this
240 acre-feet per year loss at the site of the mine and
that's going to translate into reduction of ET in this
area of so much and reduction of ET in this area of so much, reduction in spring, you know, different spring flows and perennial flowages.

And, I mean, it's probably not going to be very much for any of those 'cause it's a small number to start with, and most of it's going to be a reduction in ET, I would guess, which is a big number. So --

ROGER: If the model were extended to the west a little ways 'til it went to the pecan orchards, that would probably take care of it.

HALE: That's a constant flux boundary.

STAN: Well, I mean, not really because --

HALE: I'm joking.

STAN: -- they probably can't change anything over there. So what you have by extending the model to the west is a different diffusivity over there. You have a higher storage coefficient and a higher transmissivity, so that's going to effect how those changes propagate, you know, back around to whatever feature where water can be captured. So I don't know.

HALE: Again, I keep coming back to, our task here and what would be published and put out into the public is going to be in the context of a time
period. And that's what's going to be considered the
impact. And if we discuss something that might happen
in 10,000 years, that shouldn't be considered the
impact for the EIS period of evaluation. And if we mix
those two together, then we're --

STAN: Is there some criteria that you
have to meet?

HALE: Well, we started out at 150 years
and then went to 250 years.

STAN: No, I don't mean time. I mean
criteria for impact. You can't reduce ET by a certain
amount or you can't --

HALE: No, no. I think --

MARK: Earlier the question was posed,
is 300 years a reasonable time period? Now it seems
like we're talking about time periods much longer than
a thousand years and that's -- is that the right
discussion to be having? Should we really be focusing
more on what the best available model projections are
at what's already a very long time frame, a thousand
years, and just leave it at that?

MELISSA: Well, I think it goes back to
what Jim introduced the meeting with with what he
needs, right? I mean, he needs to understand what the
best available science is in order to make an informed
decision and in order to disclose the effects.

And so in the NEPA world, I mean, it is different. While we want to have the best available science, the best available tools in order to disclose the impacts and to predict some of those impacts, we might not necessarily, depending on how the Forest feels about it -- and Roger, feel free to chime in -- but we might not necessarily be looking for the best 10,000-year groundwater model to predict impacts 10,000 years out.

What we do need to understand is what this project, what the impacts of this project are going to have on the groundwater around it. And that's what we have up 'til this point utilized this tool for.

And so if that's the case, you know, is this the best available science that we can utilize to inform Jim's decision and to estimate what the impacts are to disclose to the public? And what's the reasonable -- what's -- within reason, what's the best available science to actually even utilize this tool to show those impacts? Is it 300 years, is it a thousand years, is it 10,000 years? That should probably be the discussion.

JIM: What I would like to know is, I mean, it's nice to know that in 10,000 years what will
happen but that's not necessarily what I need to know. The thing that I was trying to pick up from what Stan was saying was if you ran the steady state, would you be better able to predict effects within our time period? If that's not the case, if it's way past the time period, then I'm not sure that that's helpful. But if it would help to better determine effects within a thousand-year timetable --

JON: No.

JIM: You're saying no.

STAN: No. I don't think it helps in looking at what the effect is in that thousand-year time period. I think what it does is it kind of establishes the ultimate effect and it provides a limit to what the effects can be at whatever time. And that is a lot more certain than predicting what the effect is at any given time.

So, you know, there's all kinds of uncertainty, you know, with the artificial -- not just the artificial boundaries, the transmissivity, and, you know, we just don't know everything about the system; there's a lot of assumptions. And so we can be a lot more certain about the ultimate effect than we can about the timing of the effects, say, at a thousand years and, you know, it seems reasonable to me to kind
of look at that ultimate effect and if -- I mean, if that's not so bad, maybe you could sign off on it not knowing the timing. But if you're saying this is the worst -- it seems like a reasonable thing to look at is the ultimate effect. I don't know if that's helpful to you or not.

JON: But based on the models that we have, we would agree that it would likely be after the thousand years.

STAN: It appears to be so based on -- based on what Hale has shown.

TERRY: With that, can we take a short break? Cindy needs to change some batteries on her equipment. And she has to capture everything you say. So let's take about ten minutes. We can stay in here a little bit after 5:00 if we need to. I don't know what your availability is, but plan on being back here at 15 'til, please.

(A break was taken.)

TERRY: To regroup a little bit, I was chatting with Jim a little bit during the break for a second and he articulated something to me that I think he would like to see us get to today, and so I'm going to ask Jim to kind of open this up and get back into the conversation we were having before break.
JIM: Well, I think it's just probably apparently repeating what I've already said, which is basically to try to pare down to what I can understand and disclose within the time period that we have for the EIS. If there are things that we need to help us in that time period that we could come up with that would clarify or better describe what the effects are, I'm all ears to listen to that. But if it's trying to debate whether or not we want to remodel or redo or rethink things that are going to be well beyond this time frame, then that's not going to fit within the needs that we have to make an informed decision.

So based on what I've heard, we just need to pare the few remaining issues down and hear from my specialists and from our scientists here as to whether or not there's a general agreement on that time frame and the effects of that that's been displayed by Hale and Grady or if there's something still outstanding that needs to be addressed.

We only have a short amount of time here so I need to hear specifically as to whether we have any of that kind of agreement or we still have some outstanding issues, so --

TERRY: So do we all have a clear understanding of what those remaining issues are?
Could somebody say what they are?

JIM: Well, they're probably still the same as they've always been, but you've heard the discussion. So have they satisfied your concerns in any degree or are they still of such concern that they haven't been resolved?

GRADY: Just go through the list.

MELISSA: You want to just go through that list and check off whatever anybody at least -- or cross through?

TERRY: I think we need to hear from Roger and Salek as far as resolving the particular issues that have been brought forth.

SALEK: I haven't heard from Grady yet but what I've heard from Hale so far, I really needed to have the analytical back-up for what the boundary conditions, what they actually mean, and so there was a lot of -- in the project record, we'd articulated a lot of different opinions but now we've actually kind of dived in and actually started looking at the numerical justifications and all that stuff. So I'm feeling a lot better that that has been proven up.

JIM: Do you feel better that you saw them?

SALEK: Yeah, I didn't have those
before. And so just over the last month all that work has been -- has come around. It's been delivered. I mean, literally I got them yesterday. So I'm still looking at it but it appears from the discussions we've had today, from looking at the maps, the charts, the graphs, the everything that -- and the conversations that we've had about actually critiquing it, that the opinions that were presented before are lining up with what the analytical data shows, and that's what I needed to feel like I can then accept and feel like I have a foundation for accepting that.

MELISSA: So am I hearing you correctly that you're saying that you're feeling like the domain, right, because we're talking about the domain boundary, so the domain boundary you're feeling reasonably satisfied with what's been brought forward as far as making your concern -- you're feeling okay with that?

SALEK: Yes. I'm not going to go "mm-hmm". Yes. That's my first take. I just got this stuff and we're looking at it but that's my take on it.

TERRY: So assuming your take after you look it over is, in fact, how you're feeling, are you seeing new additional chunks of work that need to be done in terms of rerunning models, bringing in any other kind of models, or going down that road or do you
think that we're -- aside from going on the data that's in front of you and making sure you're comfortable, aside from that, are we essentially done? And I don't mean to put you on the spot but I know I am.

SALEK: There is always more things that a specialist would want, that's just kind of a natural way of -- but looking at what Jim talked about at the beginning of the day, the big picture, will it make a difference, those type of things, I could potentially ask for more clarifying resolution, looking at finer resolution of items and things of that nature, kind of like what Stan was mentioning earlier, but whether or not they would actually truly affect the big picture, if they would make a difference on those types of things, I'm kind of feeling like it really wouldn't at this point in a general sense. And so now that we've got -- I feel like we've kind of picked at that well and whether or not anything else would be -- would be not necessarily as productive.

So a lot of the EIS already is like what Chris was mentioning in that kind of qualitative arena anyway. It started out in the -- in earlier, earlier drafts, the first drafts tried to get into the quantitative and it was very difficult to stand on that kind of foundation, that kind of quantitative with the
kinds of back-up that we had.

And so that, after a whole series of meetings just kind of reducing that quantitative description into more of a qualitative has really helped now since we're in that qualitative. Having finer and finer resolution on anything quantitative, whether or not it'll actually do anything for the big picture is -- I feel like it probably wouldn't in that sense. But I still needed to have this step be done for me.

TERRY: Okay. Thank you.

Roger, how are you feeling about all this?

ROGER: 99 percent. Well, basically we end up having a pit and it has something on the order of 280 feet-per-year, which will be balanced by mostly ET and some stream flow loss possibly, and any temporal model we do is only going to give a percentage of that. So some people who want to know how bad can it get, say perhaps from US Fish and Wildlife Service, may be dissatisfied with that.

If we're satisfied with showing an impact to ET of 50 percent of what it might ultimately be, maybe it's good. But I feel like it's less than perfect.

TERRY: So is that relating to what --

ROGER: The steady state model would show because it does -- no longer has a change in
storage and any of these models that continue to have a change in storage, like 77 acre-feet per year, ultimately that's going to revert to loss of ET. But -- so the model that develops that, we don't know absolutely where that's going to come from.

TERRY: Yeah, I don't think we're precluded from going where Stan talked about in terms of describing -- what Salek talked about earlier in describing qualitatively, where this might be many thousands of years down the road. We just need to put it into context. I mean, we could certainly do that under NEPA.

So would that address some of the 1 percent?

ROGER: Would that be a NEPA issue? Is that satisfactory to the NEPA gurus with some discussion?

TERRY: Well, I can weigh in on that a little bit because I'm a NEPA guru.

SALEK: So if I could just talk about a reservation for a second. Potentially, if we're coming to resolution on all of this, this project has the potential of being somewhat precedent setting where we do have the off-center area of withdrawal near the boundary and so, therefore, the effects go up to the boundary. And it's not in the center and we
potentially, even though we're looking like we're proving it up, it still potentially is going to be one of the big projects that, if we go the route we're going right now, we accept something that isn't traditional. And so that's going to always be a little bit of a reservation for me.

JIM: Do we talk about that in the EIS? I mean, I heard some really good reasons why it was put where it was. So, to counteract that, should we at least describe why we did that in the --

HALE: If it's not in there, just a very direct discussion of the very low conductivity features of the west domain west of the model -- west of the pit is really what addresses that. I mean, visually, Salek, you look at it, it's near the edge. We could have made it no-flow over there, and what this constant flux brought us is telling us to some degree what the no-flow would be as well.

Really water that's moving across the western boundary is what's falling on the west side of the Santa Ritas. We could have put a no-flow up there and you would have had no-flow boundary. So, I mean, it is a classic model but you've just got a very low conductivity feature over there on the side and if you describe that in the EIS summary there, the concerns
about the boundary are allayed by the fact that there's very little flow going across there and there's a very low conductivity feature over there.

SALEK: If so on the 100-year, the 500, the 1,000, the domain cuts off the cone of depression. So potentially we're looking at accepting a model that does that and so there is this kind of -- so many square miles over on that west side that isn't represented in the model. And so it's kind of off the -- off the analysis in a way.

CORI: Not in a hundred years anyway. I mean, it's out there.

SALEK: It's out there. And so that's the reservation.

GRADY: And the resources over there that could be impacted, I mean, are there -- is there anything over there that would be disclosed as an impact? Like we're saying there's no surface water features over there to be captured and impacted as well. So from an --

SALEK: Rosemont owns a property over there; they're concerned. Either way, I'm just trying to articulate what works on the road that goes up to the effects of the boundary that's not traditional. Outside of that boundary are acres, miles that are not
within the domain that potentially are affected but we
don't -- I mean, we would -- we could look at
qualitatively addressing that. But that is still a
kind of -- that's the little bit of the uneasy that we
kind of always -- it'll be something that probably I
have a feeling will keep coming up and we will have to
like address it and talk about it and somehow deal with
it because it's nontraditional.

MELISSA: So what would resolve that for
you, that reservation? Is it something as possibly
small as putting in like a qualitative assessment of
that model boundary and all of that in the NEPA
analysis or are you talking like different model run,
expanding that whole model domain?

SALEK: That's what would solve that
completely and maybe some of the stuff that Stan
mentioned. It's not necessarily in the sense that we
just looked at all the numbers, that it isn't something
that would make a difference. But I think it'll just
be something that will keep coming up from opposition
from -- and it's just something we're going to have to
live with if we move forward with what we've got.

So it will be like a little bit of a loose end
that we'll then have to start talking about these types
of sensitivities and get into all that kind of detail
and be in the position that you're in right now sitting in that seat with those graphs and charts, the Forest Service, potentially because we accepted and we're moving on. That type of thing. So that's the reservation.

LARRY: Is there a robust description in the EIS now of the justification for the boundaries, the implications for the impacts being so close to that edge? It seems to me -- that being a rhetorical first question. It seems to me that such a robust discussion description and rationale is in the record and can then be relied upon every time the layman, the lay public, bring up and wonder why. And it's not so lay either because it was the first question we had three years ago, right? We sat down in your office and you said why are you putting it there? And we went through those discussions.

HALE: I've blanked all those out.

TERRY: Chris?

CHRIS: Well, the real answer is while there are a few sentences in there, no, the robust discussion that we've all had today is not in there yet. And we --

JIM: It could be incorporated.

CHRIS: It could be incorporated.
TERRY: It's in the record and it's just a matter of pulling it out and putting it in a user friendly manner.

LARRY: And it then being, Salek, the ordinance you need, if you will, the ability to go right back and say, yes, but here are the reasons for the particular application, each one is different. This is why it was done.

JIM: Well, the other factor here is, when we talk about the public or defensibility or potential litigation points and things like that, I have to know that, you know, from Roger's standpoint because he is the Washington office and the regional office reviewer, if they can't live with that, then it's going to come right back to me saying do it over again. So I have to have that tied up. And I can't get, you know, surprised at the end with it being remanded back to me.

MELISSA: So, Roger, what do you need for that model to be -- I mean, would you feel in your review -- I mean, would you feel confident if we could get something into the EIS that represents the process of deciding that model boundary or --

ROGER: Well, if everybody could be happy with the disclosure that this pit evaporation
will result in, say, you know, look at the thousand
year, 500-year whatever model, and say, ultimately
evapotranspiration loss will be twice as much as this.

And it's a DEIS so it will be up for the
public scrutiny and I know well that that can result in
total rewrite of the EIS because it happened to me,
which is why I'm so paranoid, I guess. But that might
do it.

A steady state model would be more robust but
we want to look at what we can get through NEPA and
make the public happy --

JIM: We're not going to make them
happy.

MELISSA: The public will not be happy
regardless. What will make you guys happy?

ROGER: The public is getting more and
more sophisticated every year and I think we all are
aware of that and I certainly saw the lag in Florida
or, you know, the EIS's were pumped out in terrible
shape, you know, they just knew they could get away
with it. But it's not as easy anymore.

And, for instance, we're all here discussing
Tom Myers. He commented on my EIS with a 200-page
comment letter. You know, you have to answer every
single point and that took a long time. But -- and our
EIS was considerably different when we released it in final form.

So I just have this desire to get it as right as we can the first time, and I think that a steady state model would at least show the limits of capture and that would be good to have. But we might have to extend at least the western boundary to be able to get that. But I do know that steady state models run faster than temporal models 'cause they, you know --

CHRIS: So can I ask a question, then, of Hale and Grady? So it sounds like if we could incorporate some kind of results from a steady state model in a qualitative sense in the EIS, it would satisfy some concerns. I guess I have two questions.

Logistically, can you do it? And, secondly, can we get the detail out of it kind of describing where that ET is being affected? Is it, you know, which reach of which creek, which stream?

HALE: Which reach? You want us to go to that level of detail?

CHRIS: Well, we would want -- for instance, it's one thing to say, you know, the ET would -- there would be 160 acre-feet or 240 acre-feet reduction in the basin. It would be much nicer to say maybe that some of the areas closer would be -- have
higher impacts, some places farther would have less. I mean, that's a question. Can we get anywhere beyond the back of a napkin percentage? Can we get some specificity out of a steady state model?

SALEK: Davidson versus Cienega Creek.

GRADY: And back up a step. So we already did the one, the steady state run with the steady state inflow rates and that, so you're basically saying the same thing, just breaking out the results in more detail; is that right?

JON: With the pit lake.

GRADY: Right, with the pit lake. And I think we did with wells.

JON: No, with the pit lake running at steady state.

LARRY: Terminal pit lake.

GRADY: Is that what you're saying?

MELISSA: Maybe. Let's ask Roger because he's the one asking for steady state.

ROGER: Well, basically, until you get to that first idealized diagram that Stan showed with the ET and stream flow balancing the outflow flux. So, in other words, no storage changes, no changes in boundary effects.

HALE: So, do you think, Roger, that we
might be at a steady state in a thousand years? Is that --

ROGER: I think temporal solution is a little deceptive. People tend to think that it's true; whereas, it's heavily dependent on accuracy of parameters, like storage. Of course, we're not absolutely sure of hydraulic conductivity either, but it's a little easier to determine in many areas than storage is. But storage really controls that time scale. I mean, it's -- to a remarkable degree.

GRADY: We've already -- so we know what the long-term impacts are going to be. It's going to be somewhere around what the inflow rate is, pit inflow rate is, at a thousand years. So if we run it out to steady state, it's just going to run it out further.

ROGER: It's not going to run out forever, only until it captures that much ET.

GRADY: I think what Jim said, anything that happens beyond that is the same.

ROGER: If we're happy on just presenting this model and stating that ultimately 200 acre-feet of ET will be captured, then we can go there and see if they'll bite.

JIM: See if you'll bite?

ROGER: See if I'll bite? I'm not going
to write a letter.

TERRY: Chris, did your questions get answered?

CHRIS: Well, I really don't want to get in the weeds on how to build a model. But here's the question. You have a steady state model but it has a boundary that is going to be -- it is going to be providing some of that flow into the pit in a steady state unless we use a constant flux model. It seems if we're going to do a steady state model just for a qualitative, ultimate impacts that could happen, we only have two choices: we've got to push that boundary out, which I don't know if that will do anything, but that seems to be what I'm hearing, or go with constant flux. So that's the question. If you were actually to try and do a steady state, what would you do to prevent that boundary from becoming an issue?

HALE: Constant flux --

MARK: There is another option. You could also vary the general head boundary conductance, couldn't you, to allow for a smaller conductance to what it is now to start approximating what it might be with a larger grid?

STAN: I don't know that we have any way of knowing what conductance to use that would give you
the same results as a larger grid.

MARK: It would be more of a sensitivity analysis, I guess.

STAN: Yeah, it would be more -- the smaller you made the boundary conductance, the more the response would approximate the constant flux boundary 'cause the drawdown would be more bouncing off of that boundary.

MARK: Right. Yeah, my concern was the constant flux boundary seems inappropriate as well.

STAN: It does. Well, it certainly affects the timing, but if that domain has all of the features where capture can occur, at least whatever's going on at the pit is being distributed among those features.

MARK: Right.

STAN: Now, if it omits some like Sonoita Creek or something where it could possibly be affected, which I'm not saying that it could be, but if there were some other connected features outside of that domain, then that's where you might consider a larger domain. But that's a major effort.

SALEK: So I heard super position model versus like maybe merging with like the Tucson AMA model or something like that. Are those possibilities
or is that total not really possible? I'm just asking here 'cause I'm not sure.

HALE: Well --

CORI: He's speechless.

HALE: I'm trying not to be dramatic.

SALEK: Okay. Don't have a heart attack.

HALE: Just for instance, the Tucson AMA model, I don't even know what it would look like if you ran it out a thousand years in terms of water balancing and things going dry.

I mean, this is just sort of peeling back issues here. So if we start to look at a larger model domain, you start to consider all sorts of different accuracies and components that if you put that out there in a quantitative presentation of a model kind of way, then you've got a whole list of defensibility things you need to address. And I've been there before. It's just a slippery slope. And you bring all this new information in you need to back it up because in this forum, this dialogue that we're having on this project, it's that type of project.

So, you know, the idea of expanding this model domain to figure out what's happening in our case with 240 acre-feet a year past year 1,000 in terms of
reduction in ET, you know, we're getting closer to that at a thousand years already. You can kind of look at the distribution already and see and it's going to take a long time for that asymptotic approach to occur and we see equilibrium.

But I guess I feel like we're looking at things well beyond the accuracy of the model distribution trying to rope in a much larger area and make that all defensible for the purpose of figuring out, you know, where that last part of the 240 is going to end up.

In my mind, we have a pretty good understanding, I think, of how ET and stream flow are related and they really are related. But the stream flow and the ET are all connected in root zones, et cetera. So as we start to lower the root zone or the water level in the root zone, that's essentially going to protect the stream flow because, I mean, you can see out there in the Cienega when they switched over from the grassland to the trees, well, the trees doubled the uptake from the grassland and dried up everything out there.

So the amount we're talking about changing things are 1 or 2 percent out there. And in trying to nail that 1 or 2 percent change in ET versus all the
other variables that are going on out there, I think we're just out there, you know, a defensible anything we want to put on paper. Kind of back to what Chris is saying, we're out there in qualitative land at that point in time.

So I think we'll open up a lot of things we need to address to get closure if we go that route.

SALEK: So that's a technical answer. A political answer --

HALE: That was more a political answer I thought.

SALEK: Either way, to politically be defensible so that it's not a nontraditional, something along those lines, it is within the realm of possibility to do this.

GRADY: So you've got the -- anything's possible.

SALEK: Sure.

ROGER: I'm glad you said that.

GRADY: But having this, your nontraditional model boundary, I mean, we've tested every possible, conceivable thing we could on it to the extent of even using this constant flux going out of it, which would be an overestimation of what the estimates are. And so I thought the idea was let's
bracket it, let's see what we've got for that and then
that would be disclosure of what the expected impacts
are. And over, you know, the time frame that we're
looking at.

I guess my concern is, we could spend forever
doing this and we're not going to come up with a
different answer, you know.

LARRY: And that's why this is now
political.

GRADY: But, I mean, that's why we have
done all these tests, to do that, to kind of go through
rigorously and kind of test those conditions and see if
they're impacting it.

LARRY: And political really means how
it's perceived. It's perception. It's really another
word for perception, and perception can be controlled
and managed, it can be managed by the right kinds of
descriptions, the right kinds of rationale, and
discussion expanded from sentences, Chris, to pages
that really pull together what we've done the last
month, what you've done in the last month. And I think
you can manage perceptions that way and, yes, Salek,
you'll be saddled with having to describe it a few
times, why in God's name did you do that. And here's
the reason.
SALEK: And that's why I brought that up. This is more of a selfish thing. Is there a way to kind of make it easier for me to make up in the future?

LARRY: This meeting's about Jim, the next one will be about you.

JIM: Well, I may be calling on all of you to help, you know, in describing what we did with my fellow agencies, EPA, US Fish and Wildlife Service, BLM, because they're all going to be commenting. Luckily they're here, so you heard the first discussion.

And, Carter, are you still there on the phone?

CARTER: I am, in fact, still here, yes.

JIM: Okay. So that's good.

CARTER: Actually, I was about to chime in. I've been unfortunately kind of on and off with other meetings and so forth. But come what may, at a certain point, it becomes about perception and I wanted to comment that I understand the difficulty. You could go on forever in terms of there's always going to be some level of uncertainty or error for not knowing the timing.

So the question is how will it affect low flow when -- you know, it has to be connected eventually to
an impact upon the beneficial use of the downstream waters or the waters within the cone of depression. So how would it affect the low flow of Cienega Creek, and if that's something you can say the percentage reduction in flow and then the likelihood that that will have on any sort of negative environmental consequence for some beneficial use, that would be, I think, probably the most valuable way of displaying information as far as public perception.

JEAN: So this really brings me back to a question that I asked Chris during the break and it seems like we've reached the limitations of what those models can tell us.

So I asked Chris how he came up with his riparian analysis basically because he couldn't use just those models and he actually told me that he had prepared a slide or slides in case that question came up. So there is another approach that he has apparently taken that has not yet been reviewed that's in the EIS in terms of addressing the impacts to the riparian areas and I don't know -- I know you said we don't have sufficient time to go into that but perhaps a very brief discussion of or some explanation of what you did would be helpful at this point to show that there is another alternative approach.
CHRIS: Right. Well, I'll throw that to Jim first, though, 'cause I have two reservations about this. One is it will get us way off track, although I do agree that it is related. And, two, the fact is that this hasn't been fully reviewed by the Forest so this kind of falls in the realm of still in progress.

JIM: Well, no, if you can summarize in a short period, that's fine.

CHRIS: Well, I won't use my slides so I'll just describe, like I did to you earlier, and try to be brief, you know, five minutes. Somebody cut me off at five.

Okay. So I had to -- the models were one tool that I had to use. And I tempered those with the information that we got back in May that you really can't trust anything less than five feet from these models. So the models were the tool, they informed the whole analysis. When we got to those levels that were less than five feet, basically I accepted that the models were telling us something could happen, I just did not take them as a quantifiable phenomena, you know. So if there's a tiny little bit of impact way out at Cienega Creek, the models are telling us that's certainly possible that could happen, but you can't quantify it and you have to run that through the mill
of all the uncertainty that you have that's associated with it.

So one level of uncertainty that I had to deal with, and let me just preface all of this was this was a squishy analysis, right? I mean, this was juggling a lot of different nonquantifiable things. So one level of uncertainty was exactly how much drawdown we're talking about and what the accuracy of these models actually is. The other uncertainty was simply time frame.

I, for my own analysis, I believe that when you start to get out hundreds of years in the future, that was very uncertain. Again, the model suggests something could happen out there but what actually might happen, very uncertain. So I had two kinds of uncertainty I had to throw into the mix.

So to break all this down, I basically came up with two time frames, near term and long term. Near term was the mine life and 50 years thereafter. Long term anything after that up to a thousand years. Totally arbitrary time frames. I mean, you could make it 100 years, you could make it 150. This was just my way of kind of roughing them out.

TERRY: They weren't arbitrary; it was professional judgment.
CHRIS: Professional judgment, there you go. And, actually, the data did actually suggest that that's kind of the cutoff I should say.

Okay. So first I -- we looked at a whole series of things. We looked at our expected impacts on perennial stream flow, we looked at expected impacts on riparian vegetation, we looked at -- specifically at Outstanding Arizona Waters, we've got five or six criteria that fed into that.

So I'll give you the nutshell results that I came up with and kind of my real quick summary of how I got there.

Cienega Creek, we're talking Upper Cienega Creek. This is the part out east of the project area. The models are suggesting that, sure, something could happen out there many, many hundreds of years in the future at very small levels. Basically, where I -- but near term there's almost certainly no impact that will happen on Cienega Creek, either perennial stream flow or riparian vegetation.

Long term I came to the same conclusion. It wasn't so much that the models weren't suggesting something could occur out there, it was just the levels we're talking about, the very long time frames, it certainly is possible but appeared to me to be very
unlikely to occur.

So really our -- what we came up with Cienega Creek, we felt we just couldn't connect the dots and reasonably say that there would be an impact to anything along Cienega Creek.

Empire Gulch is a different case; it's a little bit closer. Near term, again, certainly the models are suggesting there could be drawdown in Empire Gulch. Near term that drawdown doesn't really rise to a level where you can say, okay, I believe that. It's in the -- you know, it's on the order of a foot or two. So in the near term you could say it's certainly possible, doesn't seem likely.

Long term the models actually predict up to six feet of impact in Empire Gulch. You know what? That actually reaches a level where we could say: This very likely could occur. It is a long time in the future, we acknowledge the uncertainty there, but the models are suggesting that something real could occur here. So Empire Gulch we took a slightly different tact and we said there's still a lot of uncertainty, there's no doubt about that, but there could be impacts.

Now, those are the only two areas that we felt -- actually seeps and springs. Seeps and springs we
basically looked at anything within the five-foot drawdown contour. We assessed whether we knew anything about the source of water and then we came up with some conclusions about whether it's highly likely to be impacted, possibly could be impacted -- that's the bulk of them because we just don't know their source of water -- or some that we don't feel would be impacted at all. So seeps and springs kind of broke out, but anything within the five-foot drawdown contour was up for fair game for impacts.

With the exception of those three things, Upper Cienega Creek, Empire Gulch, seeps and springs, nothing else did we -- we did not feel that anything else was reasonably tied to the regional groundwater. And that's a bombshell because we've been talking about Davidson Canyon and Lower Davidson Canyon, and I want to make this clear: This is not black and white.

Lower Davidson, it's fed -- the perennial stream flow down there is fed by several springs, Reach 2 Spring and Escondido Spring. We have a few lines of evidence about those springs and where they get their source of water. Is it the regional aquifer, is it shallow alluvium? There again, there's no black and white answer there but we kind of weighed all of the evidence and, you know, kind of came up with, well,
most of the evidence that we have, the lines of investigation, seem to suggest that those are shallow alluvial springs. They are not tied to the regional groundwater. So Lower Davidson, as it turns out, it doesn't matter because with Lower Davidson, we really don't get that much drawdown out there anyway even a thousand years in the future. So maybe it's a moot point. But we followed the evidence and we felt that Lower Davidson would likely -- we're not talking a regional connection anyway.

But Lower Davidson and Upper Davidson and Barrel Canyon all still could be impacted by changes in surface flow, so that's a whole 'nother component that we had to take into account.

During my life we could see 30 to 40 percent reduction in surface flow as various things get cut off during construction. As concurrent reclamation happens, that water starts to flow downstream again. Ultimately, the reduction is only about 17 percent, which certainly isn't that terrible sounding when you look at it in terms of, you know, what an annual variation could be. But what we estimated, we have at least 20 years where we could have some significant changes in surface flow.

Barrel Canyon, the upper reaches of Davidson
below Barrel, there is zero riparian zones. They will remain zero riparian zones but there almost certainly will be a change in the quality of habitat. We'll have mortality of maybe some larger species. We'd have some transition from maybe some really nice oaks and walnut, I don't know, to maybe less dense, less thick zero riparian species.

But by the time you get down to the middle of Davidson Canyon and down to the Outstanding Arizona Waters, those are 12 miles away from the mine site and at that point even the changes in surface flow begin to get pretty speculative that they'll have a real impact down there.

So when we threw it all up in the air and kind of weighed it all, you know, Lower Davidson Canyon, the Outstanding Arizona Water, again, we had a very hard time connecting the dots to make it -- to really see an effect down there. So --

JIM: Well, to answer Carter's question, I thought we also took a look at the effects on seasonal variability or low flow.

Wasn't there some discussion about the effects at the worst time this could happen?

CHRIS: Right, right. So the concern with Cienega Creek and, see now, this is going back to
the draft where we took a different approach and we
were looking at the change in stream flow that was
predicted by the model. The concern is, even a very
small change in flow in Cienega Creek during the lowest
times of the season could actually dry up reaches of
the stream, could really affect certainly aquatic
species.

So I think from everything that I've talked
about, that we've talked about in the last couple of
meetings, this is not a seasonal model, period. We
cannot truly extrapolate the results of this model in
terms of drawdown, in terms of reduction in ET, in
terms of reduction in stream flow, I mean, if you rely
on those; these are just averages. We can show when
the critical times of year are for Cienega Creek, you
know, when it gets -- if you do have a change, it could
really affect things, but we just simply can't -- we
can never make this model into a seasonal model.

JIM: No. I just thought we did take
into account the fact that we did have seasonal lows.

CHRIS: Yeah.

JIM: And that applying these numbers,
we could show a percentage of that.

CHRIS: Yeah.

CARTER: So, Chris, my question to you,
so then, would it be possible or did you consider
within the bounds of uncertainty provided by the model,
if you look at the most realistic, sort of most
realistic worst case, is that something that could be
analyzed and the impact of which could be determined
and looking at the most realistic worst case, could you
say, well, even in the most realistic worst case, the
effect would only be X amount? Therefore, in reality,
you know, this is as conservative as is possible to be
and, therefore, we don't anticipate a negative effect
or is that more or less what you did?

CHRIS: Well, we actually did. Let me
actually define your term for you if you don't mind.

CARTER: Right.

CHRIS: The most realistic worst case
actually means something, I think, in the modeling
realm. To me that means the lower bound of your
sensitivity runs.

CARTER: Sure.

CHRIS: Because the sensitivity runs
basically look at all the variations you can have in
parameters within reason. So those hydrographs that we
produced --

HALE: Maybe just realistic worst case.

CHRIS: Well, realistic worst case --
HALE: Most realistic worst case.

CHRIS: Realistic worst case, how is that?

But I would take the hydrograph that shows the most drawdown from your sensitivity runs. I would take that to be what you're kind of talking about, Carter.

CARTER: Yeah, absolutely.

CHRIS: So we actually did that. One of the changes we made in the EIS was in -- all of our tables where we talk about there will be X feet of drawdown at, say, Empire Gulch, below that in parenthesis we put the range of the sensitivity analysis. So -- and, actually, that was one of the things I took into account when I was kind of juggling all this.

So I'd say if you took just those worst case hydrographs, it probably wouldn't change the conclusions much at all because they were all pretty close.

CARTER: Okay. 'Cause to me in terms of constructing a defensible document where you can say that you considered all potential impacts and full disclosure to the public, disclosing sort of the most realistic worst case, the lower boundary sensitivity analysis would go a long ways towards that.
TERRY: Okay. So we've got about 25 minutes left to wrap up today. So what we talked about doing during this period of time was to kind of recap today's meeting and give Jim a few minutes to -- for comments and if we have --

CARTER: I apologize for the interruption. Thank you for entertaining me, Chris.

CHRIS: No, problem.

TERRY: No problem.

So what I heard, and I will recap this in layman's terms, and I'll probably get it way wrong, was Salek saying that, assuming the documentation is in place that he has yet to review, that we're probably okay, he has some reservation about the boundaries and the drawdown, right?

SALEK: Mm-hmm.

TERRY: Intersecting the boundaries.

JIM: Perceptions.

TERRY: Perceptions and that sort of thing.

And there was some discussion about how we could bolster the discussion in the EIS and the record to discuss that, okay?

I heard Roger talking about doing a steady state analysis and perhaps we could suffice by
addressing that qualitatively with the "perhaps" there.

    Did I get that right?

    ROGER: I think I said with the NEPA documentation perhaps go with the model as-is and the description of the runs with the constant flux boundary and also that we expect ultimately to have reduction in ET and stream flow equivalent to the evaporation link.

    TERRY: So existing models with that additional disclosure in the document.

    ROGER: And that wouldn't require very much wording.

    TERRY: Would require what?

    ROGER: Would not require very much wording.

    TERRY: Okay. And, Stan, where are we at? You heard these two guys' positions. I know you talked about moving model positions around some. So --

    STAN: Yeah, I think that if we're looking at the thousand year time frame, the models seem to indicate that what happens will not so much be in that time frame with ET or it will be very small. It'll be after that.

    TERRY: Okay.

    STAN: And I would conclude that the models really couldn't be used to predict when that
would happen.

TERRY: And we can certainly include some discussion of that, you know, in the text of the EIS; there's no downside to doing that, of course.

CARTER: I'm sorry, just briefly. Chris, the analysis that you were talking about, did it take into account what I believe Stan was just indicating, that the impacts would likely be beyond 1,000 years? So when you were looking at this, were you just looking up to 1,000?

CHRIS: We were just looking up to a thousand years.

CARTER: Okay.

CHRIS: What I'm hearing is that we really would want to add that next step, which is impacts could occur after that, and this is what they would look like in a qualitative sense.

TERRY: And put that into a context.

CARTER: Yeah, even if the specific timing of that is uncertain.

TERRY: Yes.

JIM: I've asked Chris and Terry to try to incorporate that into the EIS.

TERRY: So from my standpoint it sounds like a framework for resolution. Am I --
JIM: Are you being overly optimistic?

TERRY: Am I being overly optimistic? I would put that out there to the group.

ROGER: On the plus side, if we expend this minimal amount of effort which should be sufficient, if nobody catches on to it and comments on it, then we're definitely done.

JIM: Right. No, I mean, right now I need to get internal, and that's what really the main thing here today was to try to get internal not necessarily consensus but at least acceptance of where we're at. And so if we can -- it sounds to me that we have a plan forward on going with additional NEPA discussion and incorporating the results from what was given to us to put that into the EIS. So I feel good about that, that we can go forward with that.

And based on what I've heard, I feel that we have good support for the conclusions that we've reached. And as you heard Chris say, we -- the numbers are what they are, but we still have to somehow qualitatively take them into a discussion with NEPA that can accurately and, best we can, describe the effects. And that's all those pieces lined up and I have to make sure that the bases for those conclusions are sufficient. And that's really what the discussion
was today, was the basis, 'cause this modeling is the basis. And if we don't get that right, then all these conclusions that he reaches are not worthwhile.

So that was important to me that we have some agreement on this basis and, from what I'm hearing, I feel like that we have that. So I want to go forward with our analysis and go forward with the discussion and get ready to put it out.

SALEK: I'd like to make a request, though, and potentially this is the consultants over here, is all of this back-up that we've just seen over the last month or two and all those justifications, kind of bundling it all up into, like, kind of Larry was talking about, a kind of this is my, like, little stand-up package of when I have to like talk about this over and over in the future, that I have something so that's something --

JIM: So you don't feel like we have that right now?

SALEK: It's all just in different spots. It's all just not in a consolidated, clean, easy-to-follow type --

JIM: So are we talking about like a tech report from them?

SALEK: Yeah, just kind of summarize all
of the work that's been done over the last month or two
and some of the work that had been done in the previous
years.

JIM: Grady and Hale, is that something
worthwhile to do, you think we can do?

HALE: Yep.

GRADY: Anything's possible.

KATHY: If I could ask for a
clarification? And all I want to know, Salek, is you
say the last month, which that's easy to do, ask them
to bundle it up and ask them to come up with their
conclusion and how it all fits with what was done
before. Are you also asking to come up with the design
criteria for the model that was agreed upon in the
meetings and put it in one spot so it's easy for you to
find? Is that what -- the previous work that you're
asking them to bundle into one spot or are you asking
for more than that in your previous work request?

SALEK: I was thinking originally of
just about the boundary stuff but that's a great idea.

KATHY: That should be easy. I was
thinking the boundary stuff and then all of the other
model criteria that was stuck in on the original model
that you would have applied the boundary flux stuff to.

GRADY: The whole story.
LARRY: The story of the boundaries.

KATHY: The water story.

SALEK: For the models.

JIM: And we will need to describe that, so having that in a report would be good.

SALEK: It's just in a lot of different little memos and a lot of different places. And so just bundling it up would be really, really helpful.

TERRY: So perhaps the Forest Service could describe that in a --

JIM: Yes, we will put it together.

TERRY: -- in a letter.

HALE: There's a lot of miscellaneous stuff in those and we responded in May of 2011 twice.

SALEK: Yeah, put them in there.

HALE: What's that?

SALEK: Throw it in there.

HALE: I'll just -- here. And then so I guess maybe filter that. There were some things that were housecleaning stuff, I guess, maybe other things that were germane to the boundary, and then some other things that were maybe not important. So maybe a little summary of how you want it all to come together.

TERRY: And I would offer up that this is a discussion at for a smaller discussion.
So we talked about the folks at the back table have been sitting patiently and not saying much, so we talked about providing an opportunity for comments, questions, anything, is that okay? You guys, anything?

KATHY: I asked mine.

TERRY: Okay. Anybody?

JASON: My boss and I have to caucus a little on what -- this was a NEPA discussion. It's what Jim needed today but there's stuff we're thinking about, so he and I have a lot of discussion to do after this and then Chris' discussion was very helpful but there was a lot of relevance to it.

TERRY: Good.

SALEK: His discussion was what? Sorry.

TERRY: Well, it's feeling to me like we're done. So unless somebody else has something they'd like to talk about, I'd like to thank all of you for your participation and I would like to have you all note that we got out 15 minutes early, which is almost unheard of, so good work everybody.

(Concluded at 4:52 p.m., the same day.)
CERTIFICATE

BE IT KNOWN that I, Cindy J. Shearman, RMR, took the foregoing proceedings at the time and place stated in the caption hereto; that I was then and there a Certified Reporter in and for the State of Arizona; that the proceedings were reduced to writing under my direction; and that the foregoing pages contain a full, true, and accurate transcript of my notes of said proceedings.

Dated this 2nd day of November, 2012.

________________________________
Cindy J. Shearman, RMR
Certified Court Reporter #50718
State of Arizona
ATTACHMENT 3

RESULTS OF CONSTANT FLUX SENSITIVITY ANALYSES PROVIDED PRIOR TO MEETING BY MONTGOMERY & ASSOCIATES
The following files were provided via e-mail prior to the October 18, 2012 meeting, by Hale Barter of Montgomery & Associates to SWCA, Forest specialists, and USGS specialists.

These files represent the results of a new sensitivity analysis. This analysis consisted of a transient modeling run in which fluxes for all boundaries were fixed at the flow values obtained from the steady-state modeling run, and not allowed to change over time.

The following files were provided:

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Description</th>
<th>Date Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drawdown contours, 20 years after mine closure, comparing baseline model run to constant-flux model run</td>
<td>10/9/12</td>
</tr>
<tr>
<td>2</td>
<td>Drawdown contours, 100 years after mine closure, comparing baseline model run to constant</td>
<td>10/9/12</td>
</tr>
<tr>
<td>3</td>
<td>Drawdown contours, 400 years after mine closure, comparing baseline model run to constant</td>
<td>10/9/12</td>
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<tr>
<td>4</td>
<td>Drawdown contours, 500 years after mine closure, comparing baseline model run to constant</td>
<td>10/9/12</td>
</tr>
<tr>
<td>5</td>
<td>Drawdown contours, 1,000 years after mine closure, comparing baseline model run to constant-flux model run</td>
<td>10/9/12</td>
</tr>
<tr>
<td>A</td>
<td>Graph of inflow/outflow rates under baseline model run</td>
<td>10/9/12</td>
</tr>
<tr>
<td>B</td>
<td>Graph of inflow/outflow rates under constant-flux model run</td>
<td>10/9/12</td>
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<tr>
<td>2 through 16</td>
<td>Hydrographs at selected points, showing all sensitivity model runs including constant-flux model run</td>
<td>10/11/12</td>
</tr>
</tbody>
</table>
EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Contour of Projected Drawdown with Constant Flux Boundary, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep

PROJECTED GROUNDWATER LEVEL DRAWDOWN 100 YEARS AFTER THE END OF MINING OPERATIONS

FIGURE 2

GIS/123.Z4_ProjectDrawdown_100yrEndMine_CF.mxd/09Oct2012
EXPLANATION

▲ Hydrograph Location

Contour of Projected Drawdown, in feet

Contour of Projected Drawdown with Constant Flux Boundary, in feet

Ephemeral Drainage Channel

Perennial Stream Reach

Perennial Spring or Seep

Cienega Creek Watershed

Proposed Rosemont Open Pit

Extent of Model Domain

Tailings Impoundment

Waste Rock Impoundment

DRAFT

PROJECTED GROUNDWATER LEVEL DRAWDOWN 400 YEARS AFTER THE END OF MINING OPERATIONS

FIGURE 3
PROJECTED GROUNDWATER LEVEL DRAWDOWN 500 YEARS AFTER THE END OF MINING OPERATIONS

EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Contour of Projected Drawdown with Constant Flux Boundary, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment

DRAFT
EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Contour of Projected Drawdown with Constant Flux Boundary, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment

DRAFT

PROJECTED GROUNDWATER LEVEL DRAWDOWN 1,000 YEARS AFTER THE END OF MINING OPERATIONS

FIGURE 5
**FIGURE A. GRAPH OF CHANGE IN SIMULATED INFLOW AND OUTFLOW RATES FOR BASELINE SIMULATION, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA**
FIGURE B. GRAPH OF CHANGE IN SIMULATED INFLOW AND OUTFLOW RATES FOR CONSTAN
T FLUX SIMULATION, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 2. SENSITIVITY OF PROJECTED DRAWDOWN AT EMPIRE GULCH SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 3. SENSITIVITY OF PROJECTED DRAWDOWN AT THE CONFLUENCE OF GARDNER CANYON WASH AND CIENEGA CREEK ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 4. SENSITIVITY OF PROJECTED DRAWDOWN AT THE CONFLUENCE OF DAVIDSON CANYON AND CIENEGA CREEK ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 5. SENSITIVITY OF PROJECTED DRAWDOWN AT CIENEGA CREEK GAGING STATION (GAGE NUMBER 09484560 NEAR PANTANO) ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 6. SENSITIVITY OF PROJECTED DRAWDOWN AT CIENEGA CREEK GAGING STATION (GAGE NUMBER 09484550 NEAR SONOITA) ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 7. SENSITIVITY OF PROJECTED DRAWDOWN AT REACH 2 SPRING IN DAVIDSON CANYON ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 8. SENSITIVITY OF PROJECTED DRAWDOWN AT FIG TREE SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 9. SENSITIVITY OF PROJECTED DRAWDOWN AT SCHOLEFIELD SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 10. SENSITIVITY OF PROJECTED DRAWDOWN AT ROSEMONT SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

Projected Drawdown using Rosemont Pit Dewatering and Post-Closure Groundwater Model (Montgomery & Associates, August 30, 2010)

- Projected Drawdown, Base Simulation
- Earliest Projected Drawdown, K*10 in Flat Fault (east)
- Latest Projected Drawdown and Maximum Projected Drawdown, 1,000 years after end of mining, K*0.1 in Ksd
- Minimum Projected Drawdown, 1,000 years after end of mining, K*10 in Ksd
- Projected Drawdown, Constant Head Boundary
- Projected Drawdown for Other Sensitivity Simulations

S:\projects\1232\1232.34\Hydrographs_sensitivity\HydrographSite09.grf 11Oct2012
Projected Drawdown using Rosemont Pit Dewatering and Post-Closure Groundwater Model (Montgomery & Associates, August 30, 2010)

SENSITIVITY OF PROJECTED DRAWDOWN AT SYCAMORE SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

FIGURE 11.
FIGURE 12. SENSITIVITY OF PROJECTED DRAWDOWN AT RUELAS SPRING ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 13. SENSITIVITY OF PROJECTED DRAWDOWN AT HELVETIA SPRING
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 14. SENSITIVITY OF PROJECTED DRAWDOWN AT CORONA DE TUCSON RESIDENCES CLOSEST TO THE PROPOSED PIT ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
**Figure 15. Sensitivity of Projected Drawdown at Singing Valley North Residences Closest to the Proposed Pit Rosemont Project, Pima County, Arizona**

Projected Drawdown using Rosemont Pit Dewatering and Post-Closure Groundwater Model (Montgomery & Associates, August 30, 2010)
FIGURE 16. SENSITIVITY OF PROJECTED DRAWDOWN AT HILTON RANCH RESIDENCES CLOSEST TO THE PROPOSED PIT ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
ATTACHMENT 4

RESULTS OF CONSTANT FLUX SENSITIVITY ANALYSES PROVIDED PRIOR TO MEETING BY HYDRO-LOGIC
The following files were provided via e-mail prior to the October 18, 2012 meeting, by Grady O’Brien of Hydro-Logic, LLC (formerly of Engineering Analytics, formerly of Tetra Tech) to SWCA, Forest specialists, and USGS specialists.

These files represent the results of a new sensitivity analysis. This analysis consisted of a transient modeling run in which fluxes for all boundaries were fixed at the flow values obtained from the steady-state modeling run, and not allowed to change over time.

The following files were provided:

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Description</th>
<th>Date Provided</th>
</tr>
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<tbody>
<tr>
<td>Drawdown contours, at end of mining, comparing baseline model run to constant-flux model run</td>
<td>10/9/12</td>
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<tr>
<td>Drawdown contours, 150 years after mine closure, comparing baseline model run to constant</td>
<td>10/9/12</td>
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<tr>
<td>Drawdown contours, 300 years after mine closure, comparing baseline model run to constant</td>
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<tr>
<td>Water level elevation contours, 300 years after mine closure, showing constant head model run</td>
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<tr>
<td>Water level elevation contours, 300 years after mine closure, showing constant flux model run</td>
<td>10/9/12</td>
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<tr>
<td>Table X</td>
<td>Mass balance comparison, 300 years after mine closure, constant head model run versus constant flux model run</td>
<td>10/9/12</td>
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<tr>
<td>2-2 through 2-16</td>
<td>Hydrographs at selected points, showing all sensitivity model runs including constant-flux model run</td>
<td>10/12/12</td>
</tr>
</tbody>
</table>
**Explanation**

- **-10** Predicted Drawdown Contour, in feet (Constant Heads)
- **-10** Predicted Drawdown Contour, in feet (Constant Fluxes)

- Extent of Ultimate Pit
- Perennial Streams
- Ephemeral Streams
- Model Boundary

**Predicted Groundwater Level**
**Drawdown at End of Operations**
*(Model Layer 17)*

**Constant Heads VS Constant Fluxes**

File: T:\GIS\Projects\110195\Figures\ConstantFluxSimulation\SimDD_EndMining_CF.mxd  UTM NAD 83 Zone 12 N

October 2012
Predicted Groundwater Level Drawdown
150 Years After End of Operations
(Model Layer 17)
Constant Heads VS Constant Fluxes

Explanation
- 10 - Predicted Drawdown Contour, in feet (Constant Heads)
- 10 - Predicted Drawdown Contour, in feet (Constant Fluxes)
- Extent of Ultimate Pit
- Perennial Streams
- Ephemeral Streams
- Model Boundary
- No Flow Cells

File: T:\GIS\Projects\100195\Figures\ConstantFluxSimulation\SimDD_150PC_CF.mxd  UTM NAD 83 Zone 12 N

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October 2012
Predicted Groundwater Level Drawdown
300 Years After End of Operations
(Model Layer 17)
Constant Heads VS Constant Fluxes

Explanation
- **100** - Predicted Drawdown Contour, in feet (Constant Heads)
- **10** - Predicted Drawdown Contour, in feet (Constant Fluxes)
- Extent of Ultimate Pit
- Perennial Streams
- Ephemeral Streams
- Model Boundary
- No Flow Cells

Legend

File: T:\GIS\Projects\110195\Figures\ConstantFluxSimulation\SimDD_300PC_CF.mxd UTM NAD 83 Zone 12 N

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October 2012
Predicted Groundwater Level Contours
300 Years After End of Operations
(Model Layer 17)
Constant Heads at Boundaries

Explanation
- 4,500: Predicted Groundwater Level Contour, in feet
- Yellow: Extent of Ultimate Pit
- Blue: Perennial Streams
- Dashed blue: Ephemeral Streams
- Red: Model Boundary
- Gray: No Flow Cell

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Mount Wrightson Wilderness

File: T:\GIS\Projects\110195\Figures\ConstantFluxSimulation\SimGWIL_300PC_CH.mxd  UTM NAD 83 Zone 12 N
October 2012
Predicted Groundwater Level Contours
300 Years After End of Operations
(Model Layer 17)
Constant Fluxes at Boundaries

Explanation
- 4,500: Predicted Groundwater Level Contour, in feet
- Extent of Ultimate Pit
- Perennial Streams
- Ephemeral Streams
- Model Boundary
- No Flow Cell

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TABLE X. SUMMARY OF MASS BALANCE DIFFERENCE BETWEEN CONSTANT HEAD BOUNDARY CONDITIONS VERSUS CONSTANT FLUX BOUNDARY CONDITIONS, 300 YEARS POST MINE CLOSURE

300 years: Ac-Ft/yr

<table>
<thead>
<tr>
<th>Net</th>
<th>Constant Heads</th>
<th>Constant Fluxes</th>
<th>Difference</th>
<th>% Difference</th>
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<td>10,106</td>
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<td>Stream</td>
<td>-2,570</td>
<td>-2,559</td>
<td>-11</td>
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<tr>
<td>Boundaries</td>
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<td>-1,652</td>
<td>115</td>
<td>7</td>
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<td>-5,623</td>
<td>-5,619</td>
<td>3</td>
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<tr>
<td>Lake</td>
<td>-392</td>
<td>-392</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Storage</td>
<td>12</td>
<td>116</td>
<td>-104</td>
<td>903</td>
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</table>

300 years: Gallons per Minute

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<tr>
<th>Net</th>
<th>Constant Heads</th>
<th>Constant Fluxes</th>
<th>Difference</th>
<th>% Difference</th>
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<tr>
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<tr>
<td>Storage</td>
<td>7</td>
<td>72</td>
<td>-65</td>
<td>903</td>
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</tbody>
</table>
Figure
Hydrograph Locations

Explanation
- ▲ Hydrograph Location and Identifier
- Model Boundary
- Extent of Ultimate Pit
- Tailings
- Watershed Boundary
- Perennial Streams
- Ephemeral Streams

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<tr>
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<td>Confluence of Gardner Canyon and Cienega Creek</td>
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<td>3</td>
<td>Confluence of Davidson Canyon and Cienega Creek</td>
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<td>Gaging Station #09484560</td>
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<td>Gaging Station #09484550</td>
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<tr>
<td>6</td>
<td>Reach 2 Spring</td>
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<td>7</td>
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<td>Scholefield Spring</td>
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<td>14</td>
<td>Singing Valley North Residences</td>
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<td>15</td>
<td>Hilton Road Residences</td>
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</table>

June 7, 2012
FIGURE 2-2. SENSITIVITY OF PROJECTED DRAWDOWN AT EMPIRE GULCH SPRING
(TETRA TECH, 2010)

NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

EXPLANATION
- Projected Drawdown, Base Simulation
- Earliest Projected Drawdown, No Davidson Canyon Dike
- Latest Projected Drawdown, Specific Storage Increased²
- Minimum Projected Drawdown, Pit Evaporation Decreased³
- Maximum Projected Drawdown, Base Simulation
- Projected Drawdown for Other Sensitivity Simulations
- Projected Drawdown, Constant Flux Simulation
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-3. SENSITIVITY OF PROJECTED DRAWDOWN AT CONFLUENCE OF GARDNER CANYON
AND CIENEGA CREEK (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-4. SENSITIVITY OF PROJECTED DRAWDOWN AT CONFLUENCE OF DAVIDSON CANYON AND CIENEGA CREEK (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-5. SENSITIVITY OF PROJECTED DRAWDOWN AT CIENEGA CREEK GAGING STATION 
#09484560 (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-6. SENSITIVITY OF PROJECTED DRAWDOWN AT CIENEGA CREEK GAGING STATION #09484550 (TETRA TECH, 2010)
Projected Drawdown, Base Simulation

Earliest Projected Drawdown, No Davidson Canyon Dike

Latest Projected Drawdown, Specific Storage Increased

Minimum Projected Drawdown, Pit Evaporation Decreased

Maximum Projected Drawdown, Base Simulation

Projected Drawdown for Other Sensitivity Simulations

Projected Drawdown, Constant Flux Simulation

EXPLANATION

- Projected Drawdown, Base Simulation
- Earliest Projected Drawdown, No Davidson Canyon Dike
- Latest Projected Drawdown, Specific Storage Increased
- Minimum Projected Drawdown, Pit Evaporation Decreased
- Maximum Projected Drawdown, Base Simulation
- Projected Drawdown for Other Sensitivity Simulations
- Projected Drawdown, Constant Flux Simulation

NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-7. SENSITIVITY OF PROJECTED DRAWDOWN AT REACH 2 SPRING IN DAVIDSON CANYON (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-8. SENSITIVITY OF PROJECTED DRAWDOWN AT FIG TREE SPRING (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-9. SENSITIVITY OF PROJECTED DRAWDOWN AT SCHOLEFIELD SPRING (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

EXPLANATION
- Projected Drawdown, Base Simulation
- Earliest Projected Drawdown, Base Simulation
- Latest Projected Drawdown, Specific Storage Increased
- Minimum Projected Drawdown, Pit Evaporation Decreased
- Maximum Projected Drawdown, Base Simulation
- Projected Drawdown for Other Sensitivity Simulations
- Projected Drawdown, Constant Flux Simulation

FIGURE 2-10. SENSITIVITY OF PROJECTED DRAWDOWN AT ROSEMONT SPRING (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-11. SENSITIVITY OF PROJECTED DRAWDOWN AT SYCAMORE SPRING (TETRA TECH, 2010)
Projected Drawdown, Base Simulation
Earliest Projected Drawdown, Specific Storage Decreased 2
Latest Projected Drawdown, Specific Storage Increased 2
Minimum Projected Drawdown, Pit Evaporation Decreased 3
Maximum Projected Drawdown, No Davidson Canyon Dike
Projected Drawdown for Other Sensitivity Simulations
Projected Drawdown, Constant Flux Simulation

NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-12. SENSITIVITY OF PROJECTED DRAWDOWN AT RUELAS SPRING (TETRA TECH, 2010)
Projected Drawdown, Base Simulation

Earliest Projected Drawdown, Specific Storage Decreased

Latest Projected Drawdown, Specific Storage Increased

Minimum Projected Drawdown, Pit Evaporation Decreased

Maximum Projected Drawdown, Specific Yield Decreased (Alluvium)

Projected Drawdown for Other Sensitivity Simulations

Projected Drawdown, Constant Flux Simulation

EXPLANATION

NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-13. SENSITIVITY OF PROJECTED DRAWDOWN AT HELVETIA SPRING (TETRA TECH, 2010)
Projected Drawdown, Base Simulation
Earliest Projected Drawdown, No Davidson Canyon Dike
Latest Projected Drawdown, Specific Storage Increased
Minimum Projected Drawdown, Pit Evaporation Decreased
Maximum Projected Drawdown, Base Simulation
Projected Drawdown for Other Sensitivity Simulations

EXPLANATION
- Projected Drawdown, Base Simulation
- Earliest Projected Drawdown, No Davidson Canyon Dike
- Latest Projected Drawdown, Specific Storage Increased
- Minimum Projected Drawdown, Pit Evaporation Decreased
- Maximum Projected Drawdown, Base Simulation
- Projected Drawdown for Other Sensitivity Simulations

END MINING (22 YEARS AFTER START)

FIGURE 2-14. SENSITIVITY OF PROJECTED DRAWDOWN AT CORONA DE TUCSON RESIDENCES (TETRA TECH, 2010)

NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-15. SENSITIVITY OF PROJECTED DRAWDOWN AT SINGING VALLEY NORTH RESIDENCES (TETRA TECH, 2010)
NOTES:
1) Parameter used in base simulation was changed by a factor of 2.
2) Parameter used in base simulation was changed by a factor of 10.
3) Pit evaporation used in base simulation was decreased by 20%.

FIGURE 2-16. SENSITIVITY OF PROJECTED DRAWDOWN AT HILTON ROAD RESIDENCES
(TETRA TECH, 2010)
ATTACHMENT 5

PUBLICATION PROVIDED PRIOR TO MEETING BY STAN LEAKE
A New Capture Fraction Method to Map How Pumpage Affects Surface Water Flow

by Stanley A. Leake1, Howard W. Reeves2, and Jesse E. Dickinson3

Abstract

All groundwater pumped is balanced by removal of water somewhere, initially from storage in the aquifer and later from capture in the form of increase in recharge and decrease in discharge. Capture that results in a loss of water in streams, rivers, and wetlands now is a concern in many parts of the United States. Hydrologists commonly use analytical and numerical approaches to study temporal variations in sources of water to wells for select points of interest. Much can be learned about coupled surface/groundwater systems, however, by looking at the spatial distribution of theoretical capture for select times of interest. Development of maps of capture requires (1) a reasonably well-constructed transient or steady state model of an aquifer with head-dependent flow boundaries representing surface water features or evapotranspiration and (2) an automated procedure to run the model repeatedly and extract results, each time with a well in a different location. This paper presents new methods for simulating and mapping capture using three-dimensional groundwater flow models and presents examples from Arizona, Oregon, and Michigan.

Introduction

“Capture” is withdrawal-induced changes in inflow to or outflow from an aquifer. The concept was first clearly articulated by Theis (1940). He explained that the source of water derived by wells as initially from storage and later can be from increased inflow to and decreased outflow from the aquifer. Bredehoeft et al. (1982) further explained concepts of capture and emphasized that development of water resources should depend on the amount of water that can be captured with acceptable consequences, not on the amount of recharge an aquifer receives. Capture that results in a loss of water in streams, rivers, and wetlands is of concern in many parts of the United States because of degradation of groundwater-dependent ecosystems and reduction of surface water supplies for which there are existing water rights.

Glover and Balmer (1954) developed an analytical solution to compute time-dependent capture of water in a river by an adjacent well withdrawing groundwater at a constant rate. Although this and related analytical solutions are still in use, numerical models such as MODFLOW (Harbaugh et al. 2000) allow more flexibility in consideration of complex aquifer and surface water geometries and heterogeneous aquifer properties. The most common applications of numerical models are to calculate capture vs. time at a few specific locations, such as existing or proposed well locations. For examples of these applications, see Bredehoeft et al. (1982), Gannett and Lite (2004), and Leake et al. (2005). In the example by Bredehoeft et al. (1982), a hypothetical aquifer system is used to show the timing of capture with two different locations of a well field consisting of many wells.

Capture can be expressed as an instantaneous flow rate of depletion of surface water or evapotranspiration at a given time or as the total volume of depletion since pumping began. In this work, it is proposed that expressing capture as a dimensionless fraction of change

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in flow divided by the withdrawal rate that causes the change in flow is most useful in understanding the expected depletion rates by pumping for any given time. Moreover, use of the dimensionless fractions in relation to pumping rate can be used to determine ultimate or steady state capture from select features of interest (such as stream reaches, springs, etc.) resulting from pumping at a particular location. If a system responds linearly to groundwater withdrawals, that fraction is independent of the withdrawal rate. For example, if the capture fraction were 0.5 for a time and location of interest, the capture rate for a pumping rate of 100 m$^3$/d would be 50 m$^3$/d, and the capture rate for a withdrawal rate of 500 m$^3$/d would be 250 m$^3$/d. Similarly, that same capture fraction could be used to compute changes in inflow to or outflow from the aquifer in response to injection of water.

Capture fractions formulated as the ratio of capture rate to pumping rate also are a type of aquifer response function that is used in management optimization models of stream-aquifer systems (Maddock and Lacher 1991; Barlow and Dickerman 2001; Cosgrove and Johnson 2004). Most applications of these types of response functions in management optimization models involve computation of response functions at select locations of pumping wells. In contrast, this work focuses on computation and display of response functions (capture fractions) over large regions to help in understanding effects of pumping location on timing of capture or locations of features from which capture may occur, within a large set of possible pumping locations in an aquifer.

Several investigators have used analytical methods or numerical models to map the effects of pumping locations on surface water resources. Jenkins and Taylor (1974) presented a map of part of the Arkansas River Valley in Colorado showing lines of equal stream depletion factor (sdf), in days. That value is the time at which accumulated change in streamflow volume equals 28% of the volume pumped by a well pumping at a constant rate. In an ideal homogeneous semi-infinite aquifer with a straight fully penetrating stream, sdf can be computed as:

$$sdf = a^2 S / T,$$

where $a$ is the distance from the pumping location to the stream, $S$ is aquifer storage coefficient (specific yield), and $T$ is transmissivity. Burns (1983) mapped areas of selected sdf values near the Platte River in southwestcentral Nebraska. More recently, the Platte River Cooperative Hydrology Study (COHYST Technical Committee 2004) used a numerical model to map the line of 28% volume depletion at a pumping time of 40 years for an area around the North Platte River in Nebraska. Regulation of the coupled groundwater-surface water system in that area dictates that capture or depletion be computed as a fraction of pumped volume since pumping begins. Peterson et al. (2008) used a numerical model to show ranges of base flow depletion as a percentage of volume pumped at 50 years for the Elkhorn and Loup River Basins, Nebraska.

An earlier version of the capture fraction calculation and mapping was presented by Leake et al. (2008b). They used a flow model of the Upper San Pedro Basin in southeastern Arizona, USA, and northern Sonora, Mexico, to display the fraction of pumping rate that is capture as a function of pumping location for several times of interest. Leake et al. (2008a) used simpler superposition models to map potential depletion of the Colorado River by pumping wells. Cosgrove and Johnson (2005) used the MODRSP code (Maddock and Lacher 1991) to compute maps of unit steady state response functions of river seepage to pumping for various reaches of the Snake River in Idaho. The unit response functions are the same as steady state capture fractions for a single feature described later in this paper. Here, transient capture fractions also are considered.

This work first describes the methods used to calculate capture fractions and difficulties related to model nonlinearity, execution time, and mass balance errors. The methods are then demonstrated using results from three field studies and one synthetic test case. The results and the utility and limitations of the method they demonstrate are discussed. Finally, conclusions about the new method are presented.

**Methods**

To compute capture using a groundwater flow model, the first step is to make a simulation without the added withdrawal to establish baseline values of all water budget components. The second step is to re-run the simulation with no other changes except for the added withdrawal. The third step is to compute changes in water budget components from the base case for select simulation times. The resulting capture curves serve a specific purpose but do not give aquifer managers a broader picture of how location and timing of withdrawals result in capture. To help fill this need, this paper presents methods for calculation of capture over large areas or volumes of an aquifer, for specific times of interest.

Examples presented in this paper use MODFLOW-88 (McDonald and Harbaugh 1988) and MODFLOW-2000 (Harbaugh et al. 2000; Hill et al. 2000) as the simulator for groundwater flow. However, the methods are generally applicable and would be useful for any groundwater flow model.

**Constructing Capture Maps**

In any groundwater model, a simulated pumping well can capture water from features represented by constant- or specified-head (Dirichlet), or head-dependent (Cauchy) boundary conditions, Neumann boundary conditions, which add or remove water at a specified flux or flow rate, do not enter into this analysis because new withdrawals do not change the flow to or from Neumann-type boundaries. The boundaries of concern in this work are those to which flow between the feature and aquifer is potentially affected by pumage, or equivalently, the flow is subject to capture. Here, they are called features.
subject to capture, or just features. Features subject to capture can be represented by an individual element, cell, or other elementary model component, or a group of components. They can represent rivers, streams, springs, lakes, and so on.

If a well at a given location withdraws water at rate, \( Q_{\text{well}} \), then at time \( t \) the capture from \( n \) features will be \( \Delta Q_{1,t} + \Delta Q_{2,t} + \cdots + \Delta Q_{n,t} \). An individual capture value, \( \Delta Q_{k,t} \), is defined as the difference between the rate of flow to or from feature \( k \) without the well withdrawing water, \( Q_{k,t} \), and the rate of flow to or from the feature in an identical simulation with the withdrawal of water by the well, \( Q_{k,t}^{'} \).

Besides capture, the other source of water to a pumped well is change in storage in the aquifer. The change in the rate of water going into or out of storage at time \( t \), \( \Delta Q_{S,t} \), is defined as the difference between the rate of flow into or out of storage without the withdrawal of water, \( Q_{S,t} \), and the rate of flow into or out of storage in an identical simulation with the withdrawal of water by the well, \( Q_{S,t}^{'} \). Quantities \( Q_{\text{well}}, Q_{k,t}, Q_{k,t}^{'} \), and \( Q_{S,t}^{'} \) are volumetric flow rates \([L^3/T]\). Here, the sign convention is that negative values represent withdrawal or flow out of the groundwater system or into storage.

A general expression for mass balance accounting for the withdrawal \( Q_{\text{well}} \) at time \( t \) is:

\[
Q_{\text{well}} = \Delta Q_{S,t} + \sum_{i=1}^{n} \Delta Q_{i,t},
\]

where \( n \) is the number of features from which capture can occur. In this equation, \( \Delta Q_{S,t} \) is the difference in total storage change over the entire model grid. The summation, \( \sum_{i=1}^{n} \Delta Q_{i,t} \), represents the total decrease in outflow to and (or) increase in inflow from all head-dependent flow boundaries in the system, or total capture. Dividing by \( Q_{\text{well}} \), Equation 2 can be rewritten as:

\[
1.0 = \Delta Q_{S,t}/Q_{\text{well}} + \sum_{i=1}^{n} \Delta Q_{i,t}/Q_{\text{well}}. \tag{3}
\]

If a system responds linearly enough to withdrawals, the capture from a particular withdrawal rate \( Q_{\text{well}} \) can be scaled proportionally to compute capture from another withdrawal rate, \( a \times Q_{\text{well}} \), where \( a \) is a multiplicative factor. Issues related to nonlinearity are discussed after the types of capture maps are defined.

The capture maps considered in this work are produced using the following basic steps:

1. Run the model without the added withdrawal, \( Q_{\text{well}} \), and save values of \( Q_{1,t}, Q_{2,t}, \ldots, Q_{n,t}, \) and \( Q_{S,t} \). Here, \( n \) is the number of features being considered. It could be one or a potentially large number, up to the number of features included in the model.

2. For the region to be mapped, run a steady state or transient model with pumpage added at one location. For steady state or at time \( t \), compute \( \Delta Q_{1,t}, \Delta Q_{2,t}, \ldots, \Delta Q_{n,t}, \) and \( \Delta Q_{S,t} \) using computed values of \( Q_{1,t}', Q_{2,t}', \ldots, Q_{n,t}', \) and \( Q_{S,t}' \) and saved values of \( Q_{1,t}, Q_{2,t}, \ldots, Q_{n,t}, \) and \( Q_{S,t} \) from step 1.

3. Compute and save the total capture value, \( \sum_{i=1}^{n} \Delta Q_{i,t}/Q_{\text{well}}, \) the storage change value, \( \Delta Q_{S,t}/Q_{\text{well}} \), and the \( x \) and \( y \) location of the well.

4. If simulations for all locations in the region to be mapped have been run, proceed to step 6. Otherwise, select a new location for pumpage and go back to step 2. For mapping capture, it may not be necessary to simulate pumpage at all grid locations. The runs involved are independent and fully parallelizable.

5. Use a GIS or other program to make a contour map of \( \sum_{i=1}^{n} \Delta Q_{i,t}/Q_{\text{well}} \) for all of \( n \) features, or \( \Delta Q_{k,t}/Q_{\text{well}} \) for a particular feature \( k \).

For the three kinds of maps considered in this work, Table 1 shows choices made in the basic procedure.

For efficiency, steps 2 to 5 should be automated with a computer program that runs the model repeatedly, each time incrementing the well location, computing capture values and saving results. Information for computing capture from all features can be obtained from model mass balance calculations. Information needed to compute capture for individual features can be obtained from separate model output of flows to and from boundaries.

Basic information needed for making a map of transient capture is shown in Figure 1A, in which capture

---

**Table 1**

<table>
<thead>
<tr>
<th>Step</th>
<th>Transient Capture from All Features</th>
<th>Transient Capture from One Feature</th>
<th>Ultimate Steady State Capture from One Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 3—features to include</td>
<td>All features</td>
<td>One feature</td>
<td>One feature</td>
</tr>
<tr>
<td>2—transient or steady state</td>
<td>Transient</td>
<td>Transient</td>
<td>Steady state</td>
</tr>
<tr>
<td>6—results to be mapped</td>
<td>Map results for capture from all features</td>
<td>Map results for capture from one feature</td>
<td>Map results for capture from one feature</td>
</tr>
</tbody>
</table>
for a time of interest has been calculated for pumping locations \(a\), \(b\), and \(c\). The feature potentially subject to capture is the main stream and a tributary. The same pumping rate, \(Q_{\text{well}}\), is imposed at first one point, then the other, then the other. At the specified time, the fractions of the pumping rate captured from the stream and tributary are 0.5, 0.7, and 0.2 at locations \(a\), \(b\), and \(c\), respectively. Differences in capture values for these three points at the time of interest are influenced by their proximity to the main stream and tributary and the distribution of aquifer properties. To make a map of transient capture, these values and values for other locations would be contoured. In practice, the maximum density of points equals the number of grid cells, mesh nodes, and so on. Values in Figure 1B represent ultimate or steady state capture from one feature only, in this case the tributary to the main stream. Capture from the tributary at location \(a\), 0.1, is the lowest because most of the capture there would be from the much closer main stream. In contrast, capture at point \(b\), 0.9, is much higher because it is adjacent to the tributary. Capture at the more distant point \(c\), 0.3, is intermediate. If the tributary and the main stream are the only boundaries or features from which capture can occur, then the ultimate capture fractions from the main stream only in this example would be 0.9, 0.1, and 0.7, respectively, for pumping locations \(a\), \(b\), and \(c\). A map of steady state capture from the tributary could be made contouring these and capture values from other pumping locations.

Regardless of the type of map (Table 1) to be created, some preliminary work must be carried out before undertaking the steps described in the following sections. These include:

1. Select a region in the model over which to construct a capture map and the grid locations in that region for making capture calculations.
2. Select a constant well pumping rate for the capture calculations.
3. Determine how to compute change in boundary flow in the model from the added well.
4. Determine the simulation times at which to map capture (for transient analyses).

The preliminary steps are best carried out by running the model several times, with an added well at a different select location each time. Capture can be computed manually and results for these locations can help in selecting the final setup for mapping capture. For example, computational error in the mass balance of changes resulting from the added pumping (Equation 3) generally decreases with increasing pumping rate, \(Q_{\text{well}}\). However, larger pumping rates increase the chances of the nonlinear responses described in the following paragraphs. Preliminary capture calculations can help in selecting a pumping rate that balances these problems. Preliminary capture calculations with pumpage at a few points near and far from features expected to be subject to capture can indicate ranges of transient capture responses. These can be used to select times for mapping capture.

Using MODFLOW as an example, calculations of capture outlined in the following sections can be made using any version of MODFLOW and the MODFLOW postprocessor Zonebudget (Harbaugh 1990). Features of interest can be represented using constant-head cells or one of the packages representing head-dependent boundaries. These include the river, drain, general-head boundary, stream, lake, and evapotranspiration packages. Most of these packages are documented in Harbaugh
and comparing capture fractions for different pumping rates. For example, Leake et al. (2008b) show computed capture and rate of change in storage through time for two locations in the upper San Pedro model using withdrawal rates of 100 and 1000 m$^3$/d. If a model exhibits highly nonlinear behavior, results of capture maps may only be valid for pumping rates close to the one used to construct the map. A map made for a particular pumping rate may nonetheless be useful in helping resource managers understand likely timing of capture. According to Leake et al. (2008b), the general effect of nonlinearity is to overestimate capture from groundwater pumping at higher pumping rates than the rate used to construct the capture map. Similarly, if attempts were made to linearize a model by keeping layer thickness (and therefore transmissivity) constant or removing nonlinearities in head-dependent boundaries, the effect would be to overestimate capture in areas where those nonlinearities are important in describing system behavior.

Additionally, in carrying out analyses of capture with a groundwater flow model, care should be taken that added pumping stresses do not change the configuration of specified flux boundaries. For example, addition of a new well can cause cells to go dry and turn off the original specified flux for the dry cells. The change in specified flux would produce a separate signal that could interfere with the estimate of capture. If this situation occurs, the options are to (1) use a lower withdrawal rate that does not cause cells to dry up or (2) ignore the calculation of capture for that location. As discussed by Bredehoeft et al. (1982), only the change in recharge induced by addition of a pumping well contributes to capture; the original recharge rate is irrelevant in the estimate of capture.

Automating Repeated Capture Calculations

Construction of a general purpose computer program to carry out steps needed for mapping capture would be possible. For examples shown here, however, custom programs were used. For the San Pedro, Deschutes, and synthetic examples (Figures 2, 3, and 5), FORTRAN programs were used. For the Kalamazoo example (Figure 4), Perl scripts were used. For each of these three examples, the program was customized for the particular model domain and model results being accessed to compute capture. These or other programming languages could be used for future analyses, as long as there is a way to repeatedly (1) construct a well package file for particular locations of interest, (2) run the model, (3) read budget results from appropriate output files, (4) make calculations of capture, and (5) save the results.

Features Simulated vs. Reality

Ideally, a model should include all head-dependent boundaries representing features from which capture can occur but should not include artificial or unrealistic head-dependent features and should not include unrealistic specified-flow boundaries that might affect computed capture at realistic head-dependent flow boundaries. Model boundaries that do not represent physical features in a way that they would respond to pumping stress
realistically are referred to here as “artificial model boundaries.” These boundaries typically are used to limit the represented model domain to an area smaller than the actual domain of the groundwater flow system. Artificial model boundaries may be specified-flow (including no-flow) and head-dependent flow boundaries. For example, no-flow boundaries have been used to terminate a model domain along a groundwater divide or along a groundwater flow line. Similarly, specified-head or head-dependent boundaries may be used to keep head in an area at a desired level and to possibly remove an area from the model in which head change is not expected. Artificial model boundaries are problematic in calculations of capture because they can affect calculation of capture from actual physical features represented with head-dependent boundaries. If artificial model boundaries exist, care must be taken to limit the extent of the capture map to locations where capture is almost entirely from head-dependent flow boundaries that represent physical features. For artificial head-dependent boundaries, some idea of how to limit the extent of the region to be mapped can be discerned by carrying out capture calculations for those boundaries. Where the value of $\Delta Q_{k,t}/Q_{well}$ for a transient model or $\Delta Q_{k,\infty}/Q_{well}$ for a steady state model is small, say less than 0.1, then effects of the nonphysical boundary (designated here by the subscript $k$) are minimal.

Similarly, if a model includes artificial specified-flow (including no-flow) boundary segments, mapped capture values may be erroneous. Care should be taken not to map capture values near these nonphysical boundaries.

Computation Time for Model Runs

Depending on the size of the region to be mapped, hundreds or even thousands of model runs may be required to construct a capture map. If possible, the model should be simplified to run efficiently for the period of time for which capture will be computed. Mapping capture does not necessarily require capture calculations for every grid cell. For examples presented in this paper, individual model run times typically were in the range of 1 to 3 min using a Windows® XP®-based computer with an Intel® Pentium® 3.0 GHz processor. The 1530 model runs needed to construct the San Pedro capture map (Figure 2) took slightly more than 2 d of computer time with serial execution of each forward run. These runs are independent and therefore are completely parallelizable.

Mass Balance in Computing Capture

When all potential features are included, the computed terms on the right side of Equation 3 should sum as closely as possible to 1.0. The difference between that value and 1.0 is the mass balance error in computing capture. These errors are numerical and indicate inadequate precision of model calculations caused by convergence criteria that are too large or possibly inadequate precision of the code. For example, a fully double precision version of MODFLOW may be needed, such as that posted on the web site for MODFLOW-2005. Because changes in storage and flow are divided by the pumping rate of the added well, $Q_{well}$, numerical errors need to be small relative to $Q_{well}$. In computing capture maps using MODFLOW, experience has shown that mass balance errors in computing capture are highly correlated to the size of the flow rate listed as “IN-OUT” on the right-hand side of the volumetric mass balance (under “rates for this time step”) in the listing file. This value should be less than a few percent of $Q_{well}$. Larger errors result in a distorted or incorrect capture map, particularly if the mass balance error is related to computed changes in flow to or from features of interest, and not to the rate of change in storage.

Superposition

If an aquifer system responds linearly to withdrawals, capture maps can be made with groundwater superposition models (Cosgrove and Johnson 2005; Leake et al. 2008a). With this approach, the model uses an initial flat water surface and values of $Q_{1,t}$, $Q_{2,t}$, . . . , $Q_{n,t}$, and $Q_{S,t}$ are zero. Change in pumping is simulated and quantities $\Delta Q_{1,t}$, $\Delta Q_{2,t}$, . . . , $\Delta Q_{n,t}$, and $\Delta Q_{S,t}$ of Equations 2 and 3 are computed directly in budget calculations of the superposition model.

Results

Results from field studies include two transient maps of capture from all features and one transient capture map for one feature. These results show the utility of the capture fraction method in the analysis of complex systems. Finally, a synthetic example is used to show the steady state capture from one feature. The examples show the insights obtainable from these types of capture maps.

Two Field Examples of Transient Capture from All Features

Two examples of maps of transient capture from all head-dependent flow boundaries are used to show results from considering pumpage from anywhere within one hydrogeologic unit (represented here by a single model layer) of a three-dimensional model and pumpage from anywhere in an entire three-dimensional model.

The first map was made using a groundwater model of the Upper San Pedro Basin in southeastern Arizona, USA, and northern Sonora, Mexico (Figure 2; Pool and Dickinson 2007). The San Pedro River and associated riparian plants are in a narrow north-south trending band along the axis of the basin. Head-dependent boundaries in this area are simulated with MODFLOW-2000 and its stream, drain, and evapotranspiration packages. The model was converted from a series of temporally complex transient model runs that include seasonal pumping and other stresses. The simplified model was constructed by taking starting conditions from the steady state predevelopment model of Pool and Dickinson (2007) and keeping all specified-flow values constant from that model constant for a 100-year period, with the exception of the added pumping well used for computing capture. The 100-year period was simulated with 100 1-year time steps.
steps. Simulation of 100 years allows the opportunity to represent capture at a variety of times, animate the progression of capture through time (see link “Video showing simulated zones of capture of surface water by groundwater pumping, upper part of the San Pedro Basin,” at web site http://az.water.usgs.gov), or display capture curves through time for specific model locations (Leake et al. 2008b; Figure 3). The grid spacing in the model is 250 m × 250 m. Pumping locations considered are at every fourth row and every fourth column, requiring 1530 model runs to compute capture values on a grid with a spacing of 1 km in both horizontal dimensions. There are five model layers. All pumping locations are in model layer 4, the layer corresponding to the lower basin fill.
Figure 3. Cutaway view of representation of capture after pumping for 10 years in the upper Deschutes Basin, Oregon, model by Gannett and Lite (2004). Along section A–B, deep pumping would result in slower capture than shallow pumping but along section B–C, this pattern is reversed.

from which most wells in the area withdraw water. The example map of capture after 10 years of pumping is shown in Figure 2. Leake et al. (2008b) also show maps for capture from pumping at 50 years, and effects of enhanced flow to the river (the reverse of capture) from recharge to the uppermost saturated part of the aquifer for times for 10 and 50 years. With effects of pumping and recharge simulated for 100 years, maps could be created at any times of interest to resource managers up to 100 years. For the case of pumping, there is a general pattern of a higher fraction of capture near the river, but capture values vary somewhat along the river. The reason for the variation in timing of capture of water from the river and riparian system is that a silt and clay layer exists and is simulated between the pumped model layer 4 and the riparian system in part of the area (Pool and Dickinson 2007).

The second example is a fully three-dimensional portrayal of transient capture from all head-dependent flow boundaries simulated using a model of the upper Deschutes Basin, Oregon (Figure 3; Gannett and Lite 2004). In this example, capture is calculated over the entire volume of the aquifer, allowing for analyses of differences in capture from both horizontal and vertical variations in pumping location. The Deschutes Basin model, constructed with MODFLOW-88, has an irregularly spaced finite-difference grid with 127 rows, 87 columns, and 8 layers of cells. The main boundaries from which capture can occur are the Deschutes River and tributaries and adjacent evapotranspiration areas. As for the San Pedro model, the Deschutes model
was modified to start with predevelopment steady state conditions and to simulate 100 years with 100 1-year time steps and constant stresses. Pumping locations considered included all of the active cells in the model domain, requiring 53,589 simulations. In this case, capture was only displayed at time of 10 years since the start of pumping. Simulation time could have been reduced by simulating less time than 100 years, with fewer than 100 time steps.

Results illuminate a number of important points about how hydrogeology represented in the model affects the timing of capture. For example, some hydrologists might assume that shallower pumping will result in more rapid capture than deeper pumping because head-dependent boundaries representing the river and evapotranspiration are at the top of the system. Results of capture at 10 years shown in the cutaway view (Figure 3) indicate that in the vicinity of section A–B, capture does indeed occur faster when pumping is shallow than when pumping is from further down in the system. However, in the vicinity of section B–C, vertical leakance between layers is low, causing drawdown from pumping at depth to propagate more quickly laterally to reach distant head-dependent boundaries. In contrast, shallow pumping near section B–C allows greater access to the larger storage capacity provided by the specific yield of the top layer, thereby slowing the propagation of drawdown toward distant head-dependent boundaries.

One Field Example of Transient Capture from One Feature

An example capture map showing transient capture from one feature was generated using the MODFLOW-based groundwater flow model developed for Kalamazoo County, Michigan (Luukkonen et al. 2004). This model has 6 layers, 154 rows, and 162 columns, and the grid spacing in the area of interest is 200 m × 200 m. The 5-year transient simulation includes pumping and recharge that varies seasonally that was retained for this example. The only change to the model was that the river package part of the observation process within MODFLOW was used to simulate the flux to individual segments of a stream network. Potential capture from the stream segment of interest by a well in the watershed of that segment is shown (Figure 4). This capture map was generated using well locations in every other row and column in layer 3 of the model within the watershed of interest, omitting cells containing the river package for the segment considered. The capture analysis required 208 model runs. At 5 years, capture from a stream to the model is shown to vary from less than 0.1 to approximately 0.8 of the pumping rate. Capture at 5 years lessens with distance from the stream segment because of ongoing storage change, as well as possible capture from head-dependent boundaries in adjacent watersheds. Results within the watershed of interest, which is part of a much larger area simulated, therefore are affected by boundaries other than the feature of interest.

One Synthetic Example of Ultimate Steady State Capture from One Feature

A synthetic model for a steady state capture map was adapted from a sample problem in Hill and Tiedeman (2007; Figure 2.1). The model has 18 rows and 18 columns with an equal horizontal grid spacing of 1000 m (Figure 5A). Upper and lower aquifers, each 50 m thick, are simulated with two model layers. An intermediate 10-m thick confining layer is simulated without use of a separate model layer. Nonuniform specified recharge occurs in the upper layer, and a river is in column 1 of the upper layer on the west side of the model domain. For this example, the river has been divided into three reaches of equal length as shown in Figure 5A. Along the east side of the model in column 18, a general-head boundary simulates subsurface connection to an adjoining hillside. The bed conductance of the general-head boundary, however, is so low that its presence does not affect capture calculations. For more information on the model setup and parameters, see Hill and Tiedeman (2007).
Figure 5. Example steady state capture map showing (A) model setup and (B) capture fraction from reach 1 as a function of pumping location in layer 1.

Mapped results of capture from reach 1 by pumping in layer 1 show that, as expected, capture is high for pumping locations near reach 1, is low for locations near reaches 2 and 3, and is intermediate for reaches to the east in which capture occurs more equally from the three reaches (Figure 5B). The nonuniform specified recharge distribution has no effect on the capture map, but if complex spatial distributions of hydraulic conductivity were introduced, shapes of the zones would be different. Similarly, if the conductance of the general-head boundary in column 18 had been high enough to allow significant capture from that feature, the computed capture zones would have been different.

Discussion

Applicability and Limitations

Capture maps are best used to help understand the relation between location of pumping and the timing of capture. They can help the modeler understand how hydrogeologic features such as clay layers or properties such as vertical anisotropy (the ratio of horizontal to vertical hydraulic conductivity) affect the location and timing of capture. Maps are made using hundreds or even thousands of model runs over a significant area represented in a groundwater model. Results shown, however, do not mean that pumping at a rate of interest from a given location is logistically, politically, or technically possible or feasible. For site-specific studies, regional capture maps can be used as a first assessment of locations at which the model-predicted capture rate is in an acceptable range. That step should be followed up with more site-specific model investigations when wells are pumped at specific locations of interest.

Beyond Capture Maps

As was mentioned previously, capture fractions are a type of aquifer response function used in management optimization models. If capture fractions are saved for different pumping times for a reasonably linear model, values can be used to compute capture for various complex scenarios without additional runs of the model. For example, capture fractions could be used with convolution to compute capture from a well with a time-varying pumping rate. A similar process could be used to compute combined capture from multiple wells at different locations. The fractions could also be used to calculate response to recharge instead of pumping.

Conclusions

The capture fraction maps presented here can be used to help water managers and the general public understand how the position of a well and time since pumping began can affect capture of water from rivers, springs, streams, and wetlands. Hydrologists generally make graphs of capture vs. time for select points of interest. Mapping capture over an area or region for a time of interest involves making many model runs, each time with a well in a different location. The process can be automated with a computer program. Types of capture maps include transient capture from all head-dependent flow boundaries, transient capture from a particular head-dependent flow boundary, and ultimate steady state capture from a particular head-dependent flow boundary. Care should be taken to assure that the mass balance in computing capture is as close to zero as possible.

Acknowledgments

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References
ATTACHMENT 6

POSITION PAPER PROVIDED PRIOR TO MEETING BY ROGER CONGDON
Problems with the Rosemont models
Roger D. Congdon, Ph.D.

9/6/2012

At issue: “Standard Industry Practices” and boundary conditions

Vladimir Ugorits, working for SWCA pronounced the Montgomery & Associates and the Tetra Tech models to be consistent with “contemporary (or current) industry standards.” I requested written evidence of these “standards.” The response was that they were not written, but that they were actually “standard industry practices.” Therefore, we have no way to evaluate them. They are vague and general guidelines that are no more than what is believed to be correct, or just an understanding of what has been or is done in the industry.

Both models are surrounded on all levels by artificial boundaries. These are fixed head conditions more appropriate to aquifers bounded by deep lakes or an ocean, not a desert environment. They represent an inexhaustible supply of water. If the water table next to them declines, then such a boundary supplies as much water as necessary to keep the water table at the boundary level. It is water that doesn’t exist.

The modeling consultants were asked to supply examples of where these kinds of boundary conditions were used in similar circumstances, and they have not yet done this. One example they did supply was from the USGS’s Death Valley Regional Flow Simulation Model. This model does have constant head boundaries on the margins, but they are at least 40 miles from the model’s region of interest, and have no influence on it. They also supplied the Albuquerque Basin Model, also from the USGS, but it is not an appropriate comparison as it does not have many constant head boundaries on the model’s margins that I was able to determine from the USGS literature.

Stan Leake of the USGS has been helping with our modeling issues, and gave us a solution. He said that we should run their steady-state models, then re-run them with a pumping well added where the pit would be. He said that will change the model mass fluxes, and that less than 10% of the change should come from the artificial boundaries; otherwise those boundaries influence the model too much and it cannot be trusted to model impacts. I performed this test, and the consultants did so as well. The Montgomery & Associates model test resulted in 51% of the additional mass flux coming from the artificial boundaries, a not insignificant number. The Tetra Tech model test resulted in at least 32% of the additional flux coming from the artificial boundaries, but they did not apparently run a steady-state pumping scenario, but rather a 1000 year model.
These references are in response to Rosemont’s letter of June 30, 2012 concerning the boundary condition issue.

From the Guide to Using Groundwater Vistas (Version 6):

Use of Boundary Conditions (Page 17)

“It is desirable to include only natural hydrologic boundaries as boundary conditions in the model. Most numerical models, however, employ a grid that must end somewhere. Thus, it is often unavoidable to specify artificial boundaries at the edges of the model. When these grid boundaries are sufficiently remote from the area of interest, the artificial conditions on the grid boundary do not significantly impact the predictive capabilities of the model. However, the impact of artificial boundaries should always be tested and thoroughly documented in the model report. **The model grid should be expanded to include more farfield conditions until the effect of these boundaries on the domain of interest is insignificant.**

From ASTM Standard Guide D5609-94, Defining Boundary Conditions in Groundwater Flow Modeling:

6.4.1: “... a specified head boundary assumes the head is independent of the stress in the model. If the stress applied to the real system will affect the head on the boundary, the boundary is stress-dependent and modeling the boundary as a specified head boundary is not a valid representation of the boundary.”

6.4.1.2: “If the boundary conditions are stress dependent, the model cannot be considered a general, all-purpose tool for investigating any stress on the system because it will give valid results only when the stresses do not impact the boundary. The study of a new stress on the same model may require the reformulation of the representation of boundaries of the model and sensitivity tests on the model boundary representation.”

From Leake and others (2010), A new capture fraction method to map how pumpage affects surface water flow. Ground Water, v. 48, n. 5, p. 690-700:

“Artificial model boundaries are problematic in calculations of capture because they can affect calculation of capture from actual physical features represented with head-dependent boundaries. If artificial model boundaries exist, care must be taken to limit the extent of the capture map to locations where capture is almost entirely from head-dependent flow boundaries that represent physical features. For artificial head-dependent boundaries, some idea of how to limit the extent of the region to be mapped can be discerned by carrying out capture calculations for those boundaries. Where the value of $\Delta Q_k/Q_{well}$ for a transient model or $\Delta Q_{k,\infty}/Q_{well}$ for a steady state model is small, say less than 0.1, then effects of the nonphysical boundary (designated here by the subscript k) are minimal.”

There are other references that could be quoted here, but these make the point.