Sur-Rebuttal Analysis of the Applicant's Experts' Rebuttal Opinions

By
Dr. Willem A. Schreüder & Dr. Devraj Sharma
Principia Mathematica Inc.

On Behalf of
The Objectors

June 19, 2000

Table of Contents [1]

Page No. [2]

[1] *This volume contains Principia's sur-rebuttal materials based upon evaluations of information produced by the Applicant's experts in support of their rebuttal opinions.*

[2] *Page numbers, and figure numbers in the list which follows, in this volume have been assigned a prefix: 'SR' denoting the fact that they correspond to Principia's sur-rebuttal findings and opinions.*

List of Figures

1.0 Introduction

The purpose of this document is to respond to materials produced by the Applicant's experts in connection with their rebuttal opinions and statements thereof. It is intended to present findings and opinions formulated in sur-rebuttal by both Dr. Devraj Sharma and Dr. Willem A. Schreüder of Principia Mathematica Inc. (Principia). These findings and opinions are based upon their analysis of the Applicant's experts' rebuttal materials and associated information together with their own qualifications, expertise and experience in matters similar to the present one.

As part of their sur-rebuttal analysis, Principia staff have evaluated: additional documents concerning modelling that were produced as recently as June 6, 2000 by the Applicant's experts; rebuttal opinions of these experts stated in letter reports dated May 1, 2000; and, additional electronic files produced by them subsequent to that date. Furthermore, Dr. Schreüder has also held face-to-face discussions with the Applicant's modelling expert, Dr. H. Eastman, and responded to the latter's questions. In addition, he provided substantial assistance to the Applicant's experts to restore Principia's tapes of its electronic files to a computer utilized by them. In the process, he was able to confirm their complete lack of familiarity and expertise in those very computing matters that are essential to develop, calibrate, verify and apply reliable mathematical models. In fact it was Dr. Schreüder, and not the Applicant's own experts, who traced the causes of their computer faults and repaired them so that the tapes could be restored and their computer used. Based upon these efforts and their own qualifications and experience, Dr. Sharma and Dr. Schreüder have been able to derive the findings to formulate sur-rebuttal opinions. This document presents them.

2.0 Information Considered

The rebuttal opinions and supporting information produced by the Applicant's experts on or after May 1 have been reviewed, evaluated and considered by Principia in preparing this sur-rebuttal findings/opinions document. The information so considered is listed below.

[1] Ault, D.V. (2000a)
"Glover Analysis of Stream Depletions, SPCUP"
Notes, Correspondence, Calculated Tables and Electronic Files Produced by Rocky Mountain Consultants, Inc. and Transmitted to Principia by Bernard Lyons Gaddis & Kahn via Letter Dated May 23, 2000.

[2] Ault, D. V. (2000b)
Transcripts of Depositions, Volumes 1-4.

[3] Bishop-Brogden Associates, Inc. (BBAI) (2000)
"Summary of Rebuttal Opinions, Case No. 96CW014"

Letter Report by G. Ross Bethel, P.E., May 1, pp 1-22 + Appendix-A & Appendix-B.

[4] Eastman, H. S. (2000)
Transcripts of Depositions, Volumes 5-7.

[5] Glover, R. E. (1974)
"Transient Ground Water Hydraulics"
Book Prepared by Professor of Civil Engineering, Colorado State University, pp 141-161.

[6] Heath Hydrology (HH) (2000)
"Review Findings, Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP., South park Conjunctive Use Project (SPCUP)"
Report by Dr. Kenneth E. Kolm and Mr. Paul K. M. Van der Heijde, April 30, pp 1-18.

[7] Hesemann, T. (2000)
"Sensitivity Analysis of Hydraulic Conductivity and Leakance for SPCUP Groundwater Model; RMC Job No. 19-3059.002.00"
Memorandum to Mr. K. Burke, June 6, 1p + 5 Figures + 27 Tables.

[8] Jehn Water Consultants, Inc. (JWC) (2000a)
"South Park Conjunctive Use Project (SPCUP) Rebuttal Opinions, Case No. 96CW014"
Part-I Rebuttal Opinions of James L. Jehn, C.P.G., May 1, pp 1-20.

[9] JWC (2000b)
"South Park Conjunctive Use Project (SPCUP) Rebuttal Opinions, Case No. 96CW014"
Part-II Rebuttal Opinions of Harvey S. Eastman, P.E., C.P.G., May 1, pp 21-56.

[10] Rocky Mountain Consultants, Inc. (RMC) (2000a)
"South Park Conjunctive Use Project Rebuttal Opinions Related to Groundwater Model and Hydrogeologic Issues, Case No. 96CW014"
Letter Report by Tom J. Hesemann, R.G., C.E.G., May 1, pp 1-10.

[11] RMC (2000b)
"South Park Conjunctive Use Project Rebuttal Opinions, Case No. 96CW014"
Letter Report by Daniel V. Ault, P.E., May 1, pp 1-8 + Appendix-A.

[12] van der Heijde, P. K. M. (2000)
Transcripts of Depositions, Volumes 1-3.

3.0 Sur-Rebuttal Findings/Opinions

3.1 Preamble:

Wherever the rebuttal opinions offered by the Applicant's experts concern statements of scientific disagreements regarding modelling facts and issues which are themselves satisfactorily covered in Principia's expert reports in this matter, statements of sur-rebuttal differences are not reiterated in this document. Further, since several of the Applicant's rebuttal experts offer nearly identical statements of differences in opinion with Principia's previous findings regarding the Applicant's modelling in this matter, this document does not contain repetitious references to each such expert's statement of differences. Rather, the rebuttal statements presented here are intended to cover all of the appropriate Applicant's experts' statements of differences in opinions to which appropriate references are provided.

It is important to emphasize three facts here. First, that Principia's sur-rebuttal analysis of the Applicant's model does *not* imply endorsement of any component of the model. Rather, the purpose of Principia's analysis is to indicate the precariousness of unverified values assigned by the Applicant to model parameters, especially since valid sensitivity analysis was not conducted by the Applicant's expert. Second, in its rebuttal report the Applicant claims to have derived model parameter values through its calibrations *[see JWC, 2000b, Part-II]*. It has been amply demonstrated in analysis by several experts that the Applicant's model has not been properly calibrated, that the status of its calibration remains poor and that the Applicant made improper changes to the so-called calibrated parameter values for purposes of making predictions. Hence, this means of justifying the assignment of parameter values is just a circular argument and is scientifically improper. Third, even the sur-rebuttal analyses conducted of the Applicant's model do not reveal the true sensitivity of prescribed parameter values, due to the manner in which the Applicant has pre-determined modelling outcomes by the various model-construction choices made by its experts.

3.2 Statement of Sur-Rebuttal Findings/Opinions:

(1) In their letter report dated May 1, 2000, the Applicant's experts refer to a 'conceptual model' or 'conceptualization' and 'schematization' of the South Park ground water system *[see Jehn Water Consultants (JWC), May 1, 2000a, Part-I, p4, p7; JWC, 2000b, Part-II, p21, p24, p40, p41; Rocky Mountain Consultants (RMC), 2000a, p1, p2, p3; Heath Hydrology (HH), p9, p10, p14]*, when conferring their blessings upon the Applicant's modelling work in this matter. However, the relevant details of this so-called conceptualization have not been adequately identified in the modelling reports prepared by the Applicant's own modelling experts. Indeed the Applicant's modelling expert indicates that it was never their intention to do so *[see JWC, 2000b, Part-II, p43]*. The Applicant's mathematical model however has been demonstrated in Principia's reports to depart significantly, in important respects, from those conceptual-model features that are contained in the Applicant's experts' reports. Hence, it is irrelevant in the present matter for the Applicant's rebuttal experts to continually

hark back to the Applicant's conceptualization and schematization of the South Park ground water system when in fact the Applicant's own mathematical model remains unfaithful to it in significant respects.

(2) The Applicant's rebuttal experts who have blessed the Applicant's model *[see for example P. v d Heijde, Deposition, Vol-3, p418, p419]* appear to be ignorant of either the predictive purposes of the Applicant's ground water model or whether their conceptualization of the South Park Ground water system was ever actually implemented in the model. Principia's sur-rebuttal finding is that not only are such features of vital importance in establishing the model's reliability in making quantitative predictions but that such ignorance is precisely the reason why the model's reviews by the Applicant's experts has remained so poor.

(3) The Applicant's experts adopt the concept of long-term averaging to develop their method of model calibration and to describe the relatively small quantity of stream depletions calculated by the Applicant's flawed model and mentioned in their reports *[see Modelling Reports, JWC, 1997 & 1998]*. The Applicant's experts offering rebuttal opinions on this topic repeat this theme in conferring their blessings upon this model. In context, adopting such an averaging process entirely mis-represents the significant temporal variations, viewed within daily, weekly or even monthly time spans, in stream flows, in stream-aquifer interactions and hence in the depletions of these streams caused by the Applicant's proposed project pumping. This fact has been acknowledged by the Applicant's own rebuttal expert on modelling *[see P. van der Heijde, Deposition, Vol-2, p309]*.

(4) Unsubstantiated statements of disagreement offered by the Applicant's rebuttal experts notwithstanding *[see JWC, 2000b, Part-II, p46]*, the assignments of ground water recharge rates to model grid cells by the Applicant, remains flawed. The assignments remain based upon calculations that are in error. The numerous assumptions embedded in these assignments still have not been demonstrated as valid for the South Park ground water system, no matter how often the purported conceptualization and schematization of this system is offered by the Applicant's rebuttal experts as rationale *[see above]*. The central purpose of the Applicant's ground water model is to calculate the locations, quantities and timing of stream depletions caused by the Applicant's proposed pumping. The validity of recharge value assignments in this model is thus a vital component of establishing its reliability in making just such calculations. Invalid recharge assignments alone render it incapable of making reliable stream-depletion calculations.

(5) Despite the completeness in purported conceptualization and schematization of the South Park ground water system claimed by the Applicant's rebuttal experts *[see above]*, the domain actually selected by the Applicant for purposes of ground water modelling remains unverified and flawed. No sensitivity analyses appears to have been conducted to establish the validity of excluding certain geological units or portions thereof from modelling consideration or of representing others. The importance of this requirement has been

acknowledged by the Applicant's rebuttal expert *[see P. van der Heijde, Deposition Vol-2, p146]*. Thus, the representation of the South Park ground water system in the Applicant's ground water model remains flawed and is not based upon good science. Such flaws, in turn, remain to affect the prescription of general-head boundary conditions by the Applicant's modelling expert, and their influences upon recharge rates prescribed on model boundaries. Such prescriptions affect the calculated ground water flows as well as the aquifer-stream interactions in quantitative respects. The flaws prevent the model calculations in these and related respects from being reliable.

(6) Notwithstanding the unsubstantiated rebuttal opinion offered by the Applicant's experts *[see JWC, 2000b Part-II, p42; RMC, 2000a, p3]*, the numerical grid-cell size used in the Applicant's ground water model to represent significant components of recharge and discharge in the ground water model, remains too coarse to provide reliable results. This remains particularly true of grid cells used to represent stream-aquifer interactions, consumptive use by vegetation, spring flows, etc. The Applicant's own rebuttal expert on modelling himself acknowledged in his recent deposition testimony, *[see P. van der Heijde, Deposition Vol-3, p395]*, that smaller sizes of grid cells would be required to develop a reliable model, in appropriate respects, of the South Park ground water system. The following exchange is significant in this respect:

"Q: (Mr. Culichia) If the purposes of the model were to quantify - specifically quantify stream depletions in amount and time as a result of project operations, would you want to vary a grid size rather than the uniform 1,000 by 1,000?
A: It's a hypothetical question, but, in that case, I would prefer to have more resolution near streams.
Q: What type of resolution do you mean by 'more'?
A: Probably closer to 300 - 250, 300 feet."

(7) Notwithstanding the unsubstantiated rebuttal opinion offered by the Applicant's modelling experts *[see JWC, 2000b, Part-II, p43; RMC, 2000a, p3]*, the choice of one-month stress period lengths implemented in the Applicant's ground water model remains entirely unsuited for purposes of predicting the rates of stream flows and hence the depletions to streams. Even the Applicant's own rebuttal expert acknowledged in his recent deposition testimony, *[see P. van der Heijde, Deposition Vol-2, p310, p311]*, that much shorter stress-period lengths of the order of ten days would be required to develop a reliable model of stream-aquifer interactions in the South Park ground water system. This particular stress-period length is not endorsed in sur-rebuttal by Principia. On the contrary, it is Principia's sur-rebuttal finding that it is scientifically improper to pre-judge a stress-period length without conducting sensitivity analysis first. The Applicant did not conduct such tests.

(8) Notwithstanding the unsubstantiated rebuttal opinion offered by the Applicant's modelling expert *[see JWC, 2000b, Part-II, p48]*, the assignment of constant values to stream stage in the stream package segment of the Applicant's ground water model remains a very serious

flaw. This assignment prevents the model from representing the real-life manner in which stream stage adjusts itself to match the actual rates of flow in streams within each reach sought to be represented in the Applicant's model. The Applicant's own rebuttal expert on modelling himself acknowledged in his recent deposition testimony *[see P. van der Heijde, Deposition Vol-3, pp330-335, p393]*, that in modelling streams in a proper ground water model, not only does stream stage vary spatially and temporally in concert with stream flows but that it is essential to represent them properly in order to develop a reliable model of the South Park ground water system.

(9) Notwithstanding attempts to discount it by the Applicant's rebuttal experts *[see JWC, 2000b, Part-II, p47; Bishop-Brogden Associates, Inc. (BBAI), p8]*, the disconnection between the Applicant's surface water and ground water models remains as a serious flaw to prevent either one from representing stream flows and stream-aquifer interactions properly or to estimate the consumptive use and depletions to streams caused by the Applicant's proposed project well pumping. Since this is central to the Applicant's ability to quantify impacts caused by such pumping, the model's predictions cannot be relied upon.

(10) Notwithstanding the unsubstantiated rebuttal opinions offered by the Applicant's ground water modelling expert *[see JWC, 2000b, Part-II, p50, p51, p52]*, the representation of evapotranspiration (ET) in the Applicant's model, and especially the lack of faithfulness in representing knowable areas of vegetative consumptive use, the knowable coverage of such areas within affected model grid cells and proper depth functions for each type of vegetation, is seriously flawed. It prevents the Applicant's model from calculating the timing, locations and rates of consumptive use by vegetation with any reliability. Hence, it is incapable of calculating the salvage of such ET caused by the Applicant's proposed project pumping with any reliability. Since such areas of vegetative growth generally occur in the vicinity of streams flowing within the South Park ground water system, these flaws thus prevent the model from calculating either ET salvage or stream depletions reliably.

(11) Notwithstanding the unsubstantiated opinion offered by the Applicant's modelling expert *[see H. Eastman Deposition, Vol-6]*, the ad hoc adjustments made in the Applicant's model to the easily knowable elevations of the ground surface required for, and used in, making ET calculations in the Applicant's ground water model, prevent it from properly representing vegetative consumptive use rates and thus prevents it from calculating either ET salvage or stream depletions with any reliability.

(12) Notwithstanding the unsubstantiated rebuttal opinion offered by the Applicant's modelling expert *[see JWC, 2000b, Part-II, p55]*, in attempts to discount their consequences, the numerous errors identified by Principia in the Applicant's ground water model, and unambiguously identified in its four-volume expert report, remain to cripple its reliability as a quantitative predictive tool. Claims made in the Applicant's rebuttal experts' opinions *[see JWC, 2000b, Part-II, p45, p47, p48, p53, p54, p55]* that some of these should have no

quantitative consequences upon the quantities predicted by the model are baseless. Despite these claims, neither credible explanations for their widespread occurrence nor quantitative evidence of their claimed insignificant consequences have yet been offered by them.

(13) The unsubstantiated claims of some Applicant's rebuttal experts *[see JWC, 2000b, Part-II, p55]* to have conducted a peer review of the Applicant's modelling of the South Park ground water system, clearly do not stand up to scientific scrutiny. Either proper, independent peer reviews of the Applicant's modelling were not conducted at all, or, if some form of reviews were indeed conducted *[see HH, p2-p8]* most of the numerous errors in this modelling were either never detected or if detected, were ignored. In either event, this failure speaks very poorly both of the quality and impartiality of such reviews.

(14) Notwithstanding the rebuttal opinion offered by the Applicant's modelling expert *[see JWC, 2000b, Part-II, p53, p54, p55]*, the choices regarding calibration targets for the Applicant's ground water model, the method of calibration actually implemented by him and the very methods by which the satisfactoriness in model calibration status were evaluated, are fatally flawed. Reports produced in this matter by several Objectors' experts have unambiguously identified these. These serious calibration flaws when viewed together with the absence of documentation concerning significant components of this vital step, indicate that the Applicant's modelling expert did not and still does not understand the purpose of model calibrations, its significance in demonstrating quantitative uniqueness of its predictions and in establishing the faithfulness of its model to knowable reality as well as the reliability of its predicted results for purposes of quantitative decision making in this matter. The status in calibration of the Applicant's ground water model to apparently 'long-term average' hydrogeologic conditions, themselves unproven, is not only non-unique and thus unreliable but makes matters worse when considering the fact that under transient, i.e. more realistic, conditions the model remains uncalibrated. Thus, notwithstanding the rebuttal opinion offered by the Applicant's modelling expert *[see JWC, 2000b, Part-II, p54]*, his unprecedented modifications to the model's so-called 'calibrated' parameter values for purposes of making predictive runs, demonstrates this fact.

(15) Uniqueness of mathematical model predictions implies that a model produces output that is uniquely attributable to a given set of prescribed parameter values. Should different combinations of such input values, based upon equally probable estimates of unmeasured quantities, result in identical predictions by the Applicant's model, then these predictions are characterized as non-unique. Should a set of parameters, differing only in minor respects from that selected by the Applicant, cause the predicted results to vary in quantitatively substantial ways, the model predictions are also characterized as non-unique. Principia's sur-rebuttal analysis has demonstrated that the Applicant's ground water model produces non-unique predictions and cannot be relied upon in this matter for any quantitative purpose.

(16) Notwithstanding ambiguities in opinions offered by the Applicant's rebuttal experts *[see HH,*

p11], and the mis-representations of guidelines as "standards", the complete absence of model verifications by the Applicant's modelling expert remains particularly disturbing. As Objectors' experts have established based upon a proper command of the subject, that independent verifications of the Applicant's model being the only means of establishing its reliability as a predictive tool, remain to be demonstrated. Without such verification the various flow quantities predicted by the model, which contains so many errors and unsubstantiated assumptions, simply cannot be relied upon for making any decisions in this matter.

(17) The absence of quantitative data concerning several components of the South Park ground water system has been invoked by Applicant's rebuttal experts as the reason why model calibrations were undertaken in the manner they were and why model verifications were infeasible. The absence of such data cannot now be accepted as a valid excuse for implementing improper scientific practices. The burden falling properly upon an Applicant is to ensure that such data are available or to collect them through measurements before embarking upon a model development exercise that is known to demand such data and a high degree of reliability. Indeed, the Applicant's own rebuttal experts have unambiguously acknowledged, in their Exhibit-Z accompanying the Applicant's modified Decree, that precisely such data collection is a pre-requisite to undertaking reliable modelling.

(18) In their rebuttal opinions, several of the Applicant's experts express unsubstantiated disagreements with criticisms of the Applicant's ground water model that were presented in Principia's reports in this matter. While expressions of disagreements are understandable, the fact that none of these are documented with established facts, or with measurements made in the South Park ground water system or even with appropriate sensitivity tests of the model parameters, cannot and should not be accepted as valid science.

(19) Notwithstanding the rebuttal opinions offered by the Applicant's experts *[see JWC, 2000b, Part-II, p47, p48, p49]*, the predictions of stream-aquifer interactions and stream depletions made by the Applicant's ground water model are fatally flawed. Sur-rebuttal analysis conducted by Principia of the Applicant's NOCUP model simulation clearly demonstrate that the streams flowing through South Park, even as poorly represented in the Applicant's ground water model, exhibit substantial sensitivity to the prescription of stream stage in model grid cells. Figure SR-1a illustrates the gaged flow in Tarryall Creek near Como, used for purposes of such sensitivity testing. The depth of water in this stream is related to its stream flow by a power-law expression. This expression dictates the fact that the daily average depth will not equal the depth calculated from the daily average flow rate for any other span of time. Figure SR-1b illustrates the stream-aquifer interactions, i.e. gains and losses, calculated by the model during its NOCUP9a run conditions for three possible stage prescriptions. The first, depicted by a red line is simply the result of constant-stage prescription exactly as used by the Applicant and defended as appropriate and proper by the Applicant's rebuttal experts. The second, depicted by a green line, involves the calculation

and use in the model of a monthly-average stream stage. The third, depicted by a blue line, involves the calculation and use in the model of a daily-average stream stage based upon stress periods of one day. It may be observed in this figure that the stream-aquifer interaction calculated by the Applicant's model for changes in just this variable, are very significant., thus demonstrating that the model is incapable of predicting stream depletions in time, place and amount with any reliability.

(20) Notwithstanding the rebuttal opinions offered by the Applicant's experts *[see JWC, 2000b, Part-II, p47, p48, p49; van der Heijde Deposition, Vol-3; Eastman Deposition, Vol. 6]*, the predictions of stream depletions made by the Applicant's ground water model remain fatally flawed. Principia's sur-rebuttal analysis has clearly demonstrated that the depletions to streams flowing through South Park, as predicted by the Applicant's model, are extremely sensitive to even minor variations in hydraulic conductivity of the aquifer materials through which they flow. Examples are presented in Figure SR-2a through Figure SR-2e of five different streams in which the increases and even decreases to predicted depletion caused by hydrogeologically small changes to the prescribed hydraulic conductivity values, can be clearly observed. Principia's sur-rebuttal analysis is corroborated by sensitivity analysis only recently conducted by RMC as reported in their June 6, 2000 memorandum.

(21) Notwithstanding the rebuttal opinions offered by the Applicant's experts *[see JWC, 2000b, Part-II, p50, p51]*, the representations of vegetative consumptive use in, and predictions of evapotranspiration (ET) salvage by, the Applicant's ground water model are fatally flawed. Since this model remains as the only tool that Applicant retains to estimate ET salvage in this matter, it is important to evaluate these flaws. Sur-rebuttal analysis conducted by Principia clearly demonstrate that, even when based upon the flawed representation of vegetation consumptive use in the Applicant's ground water model, the quantities of ground water claimed to be salvaged in South Park are extremely sensitive to the prescribed values of hydraulic conductivity. Figure SR-3a clearly demonstrates this sensitivity of its predictions to even minor changes in the unmeasured but prescribed values of hydraulic conductivity in the model. Principia's analysis in this respect does not imply any endorsement of these values. Furthermore, that the unsubstantiated rebuttal opinion offered by the Applicant's modelling expert *[see JWC, 2000b, Part-II, p51]* that the prescriptions of ground surface elevation in the context of ET and recharge representations are not incorrect is demonstrably false is depicted in Figures SR-3b and SR-3c and in the hydrographs contained in Principia's previous supplementary report.

(22) To counter the numerous criticisms of the Applicant's model made by Objectors' experts and documented in their reports, the Applicant's rebuttal experts at RMC have recently attempted to corroborate the claimed reasonableness of stream depletions predicted by their ground water model. They have done so by modifying the computer program for Glover-Method analysis developed by the Colorado State Engineer's Office and creating an analytical model of the upper Tarryall Creek basin. Principia has evaluated this approach and concluded that

the simplistic analytical solution known as the "Glover Method" does not and cannot properly represent the complexities of the South Park ground water system. This is due to the large number of simplifying assumptions made in order to derive the analytical solution and the fact the South Park ground water system cannot be represented with such assumptions. In fact, this was the very reason that the Applicant's experts spent over two years trying to build a numerical model of the system using the **MODFLOW** computer program. Now, in rebuttal, the Applicant's experts claim that the Applicant's numerical ground water model predictions are reasonable and in line with its Glover Method analysis. Principia's sur-rebuttal analysis indicates that wherever results predicted with this method appeared to be somewhat similar to those of the Applicant's ground water model, it was because the identical property values were assigned to the two procedures. Since they both seek to represent ground water flows, it is not surprising to Principia that this result was achieved. However, when Principia evaluated the large number of assumptions embedded in the Glover Method *[see Glover, 1974]*, and ran sensitivity tests of property values utilized with it, a significantly different picture emerged. This picture is depicted in Figure SR-4a through Figure SR-4d. The depletions to Tarryall and Michigan Creeks predicted by the Applicant's ground water model and its application of the Glover Method are illustrated in Figure SR-4a. The significant differences between the two procedures even for the identical property assignments may be clearly observed. The sensitivity of stream depletions predicted by the Glover Method to prescriptions of specific yield are illustrated in Figure SR-4b, for the same two streams. Likewise, the sensitivity of the Glover Method to prescribed transmissivity values is illustrated in Figure SR-4c. In calculating the aquifer transmissivity for use in this analysis, the Applicant's expert used the well's screen interval in the aquifer to calculate a different transmissivity value for each well. This is clearly incorrect and runs counter to the Glover Method assumptions. If a constant aquifer average transmissivity value is used for each well, the predicted depletions will be greater as illustrated in Figure SR-4d. It will be apparent by now, and not surprisingly, that the magnitude of stream depletions predicted by the Glover Method depart very significantly from those predicted by the Applicant's ground water model. Hence, the Applicant's experts' rebuttal opinions regarding this matter are entirely without merit.

Gaged Flow: Tarryall Creek near Como

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

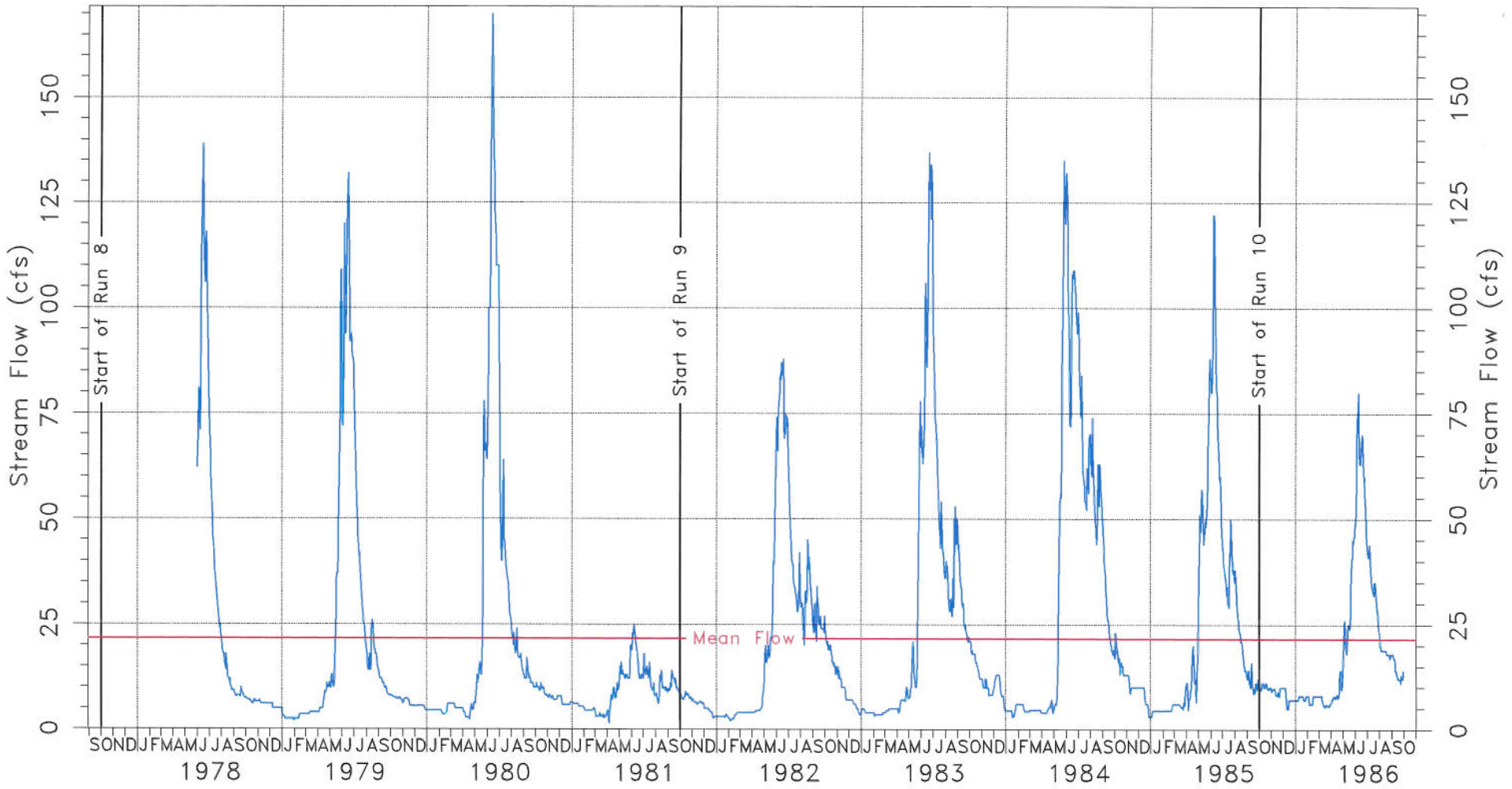


Figure SR-1a.

Tarryall Creek Stream Leakage

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

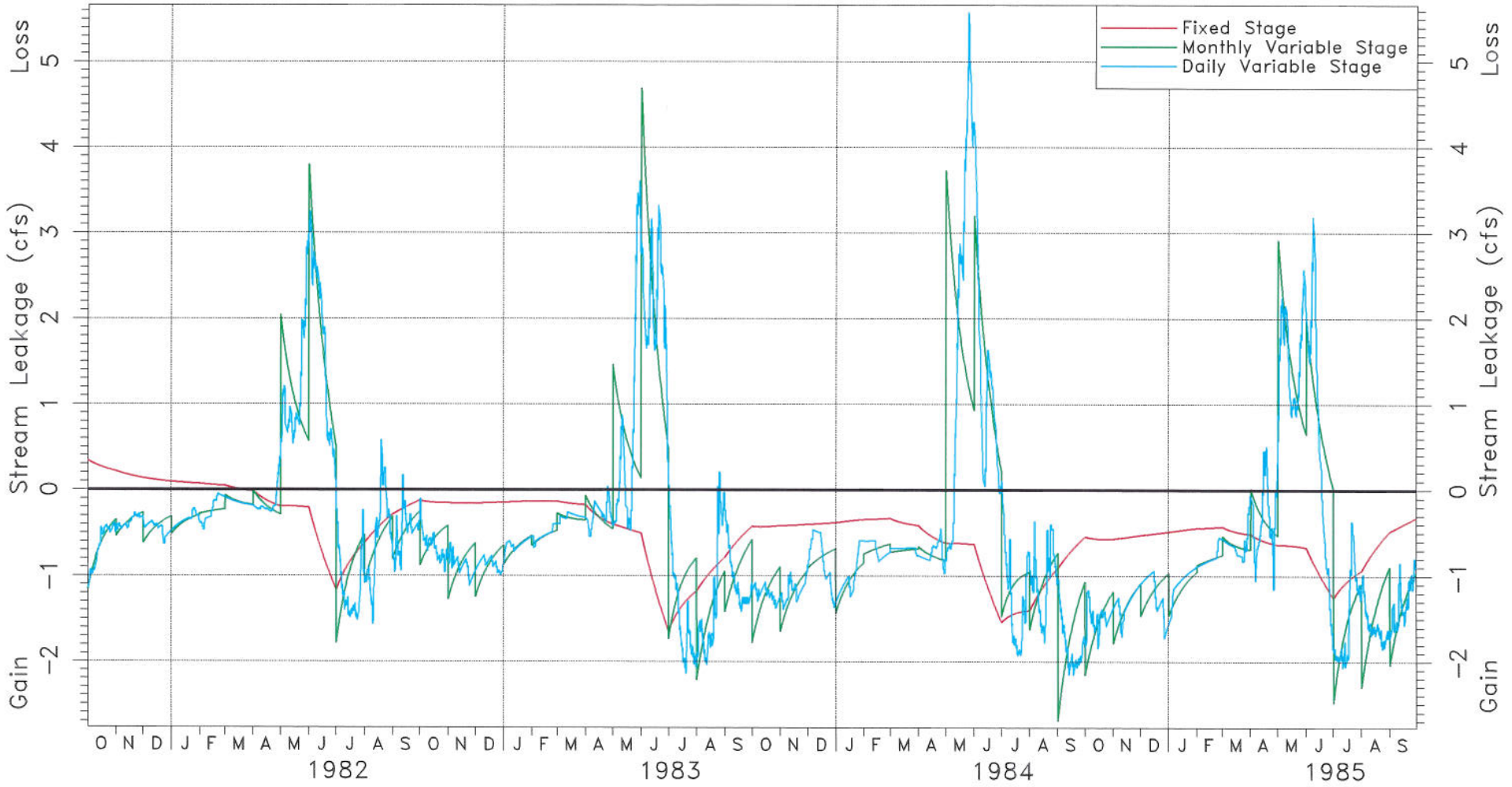


Figure SR−1b.

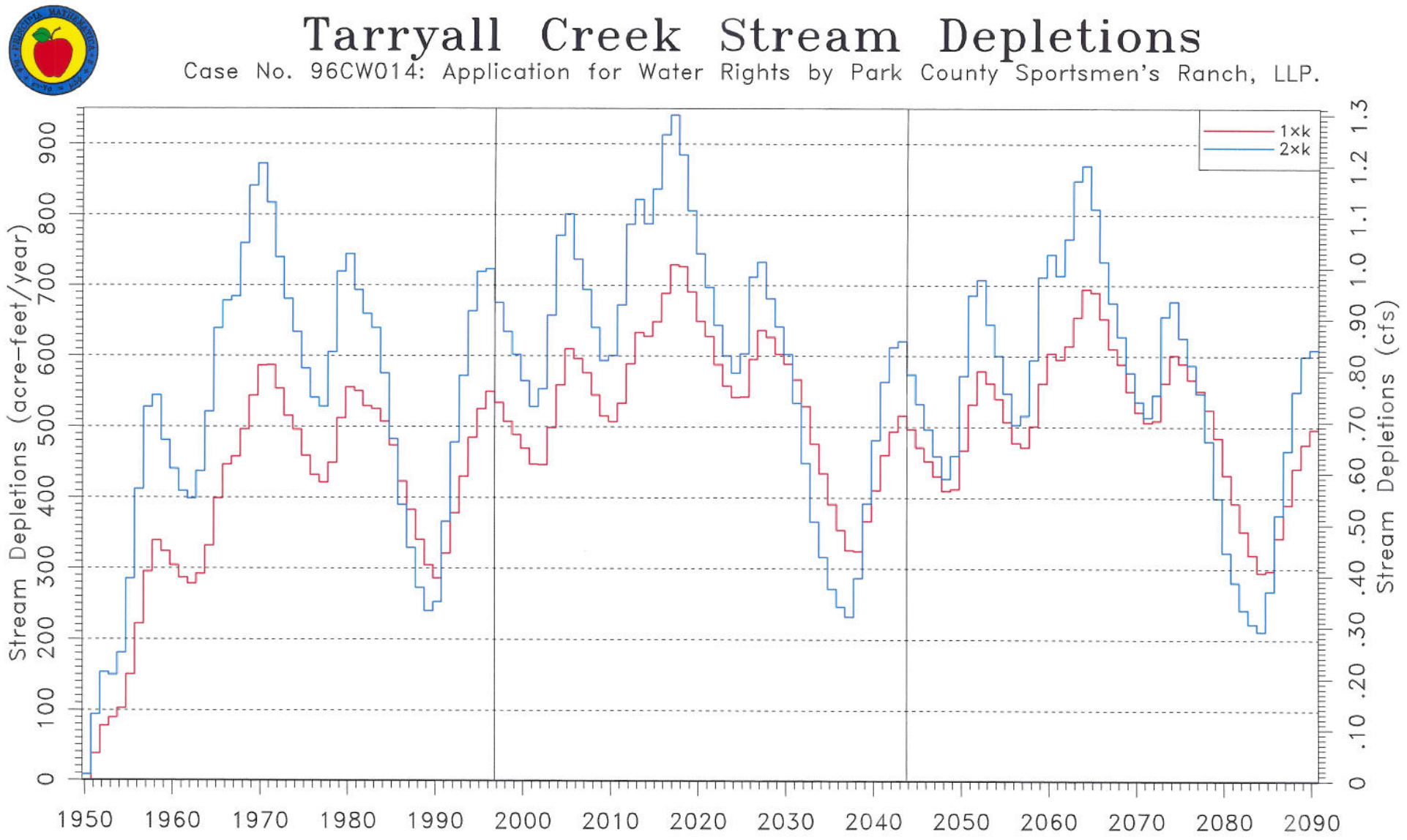

Tarryall Creek Stream Depletions
Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.
Stream Depletions (acre-feet/year)
Stream Depletions (cfs)
1×k
2×k
0
100
200
300
400
500
600
700
800
900
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.0
1.1
1.2
1.3
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

Figure SR-2a.

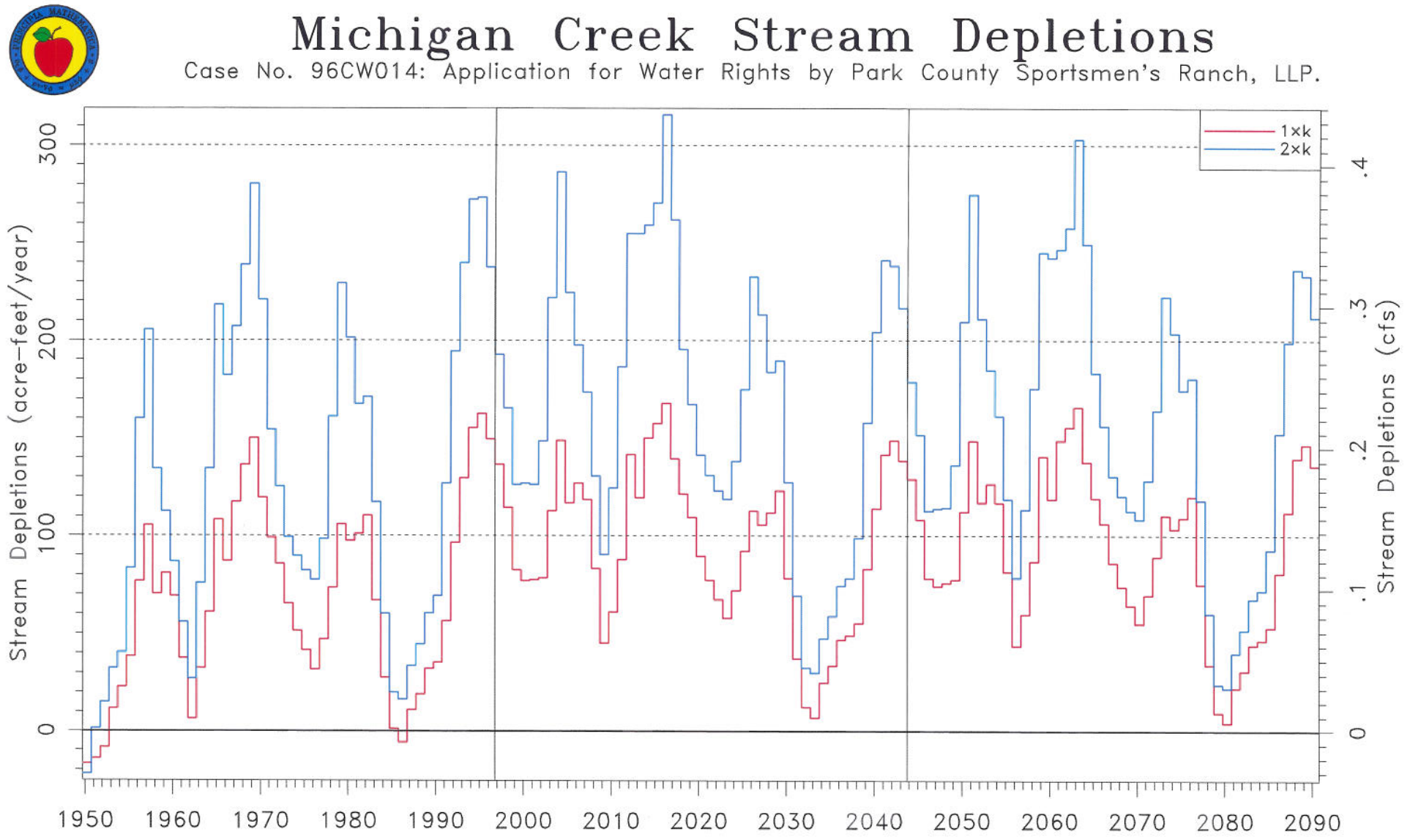

Michigan Creek Stream Depletions
Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.
Stream Depletions (acre-feet/year)
0
100
200
300
Stream Depletions (cfs)
0
.1
.2
.3
.4
1×k
2×k
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

Figure SR-2b.

Jefferson Creek Stream Depletions

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

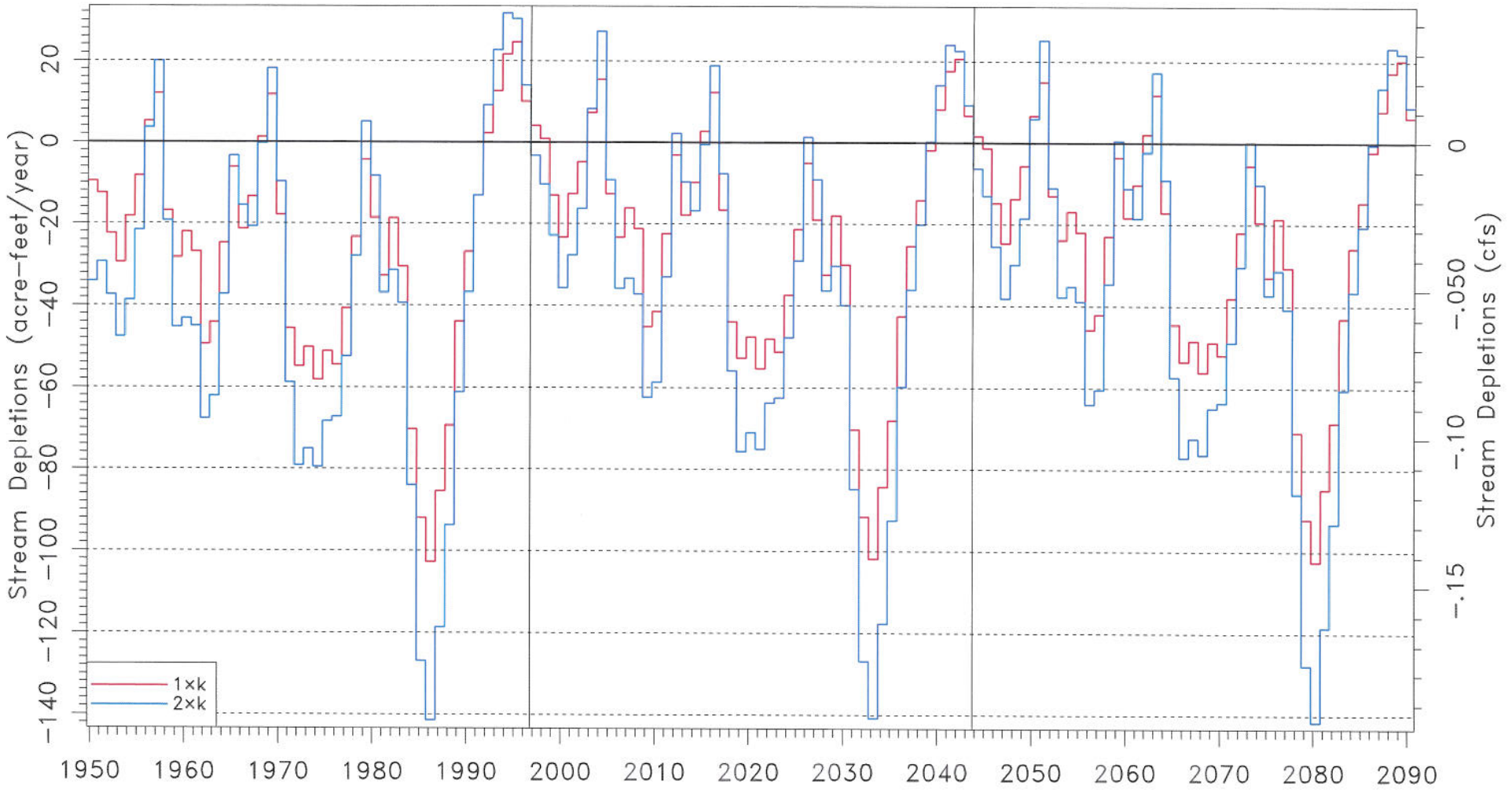


Figure SR-2c.

Garcia & Sevenmile Creek Stream Depletions

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

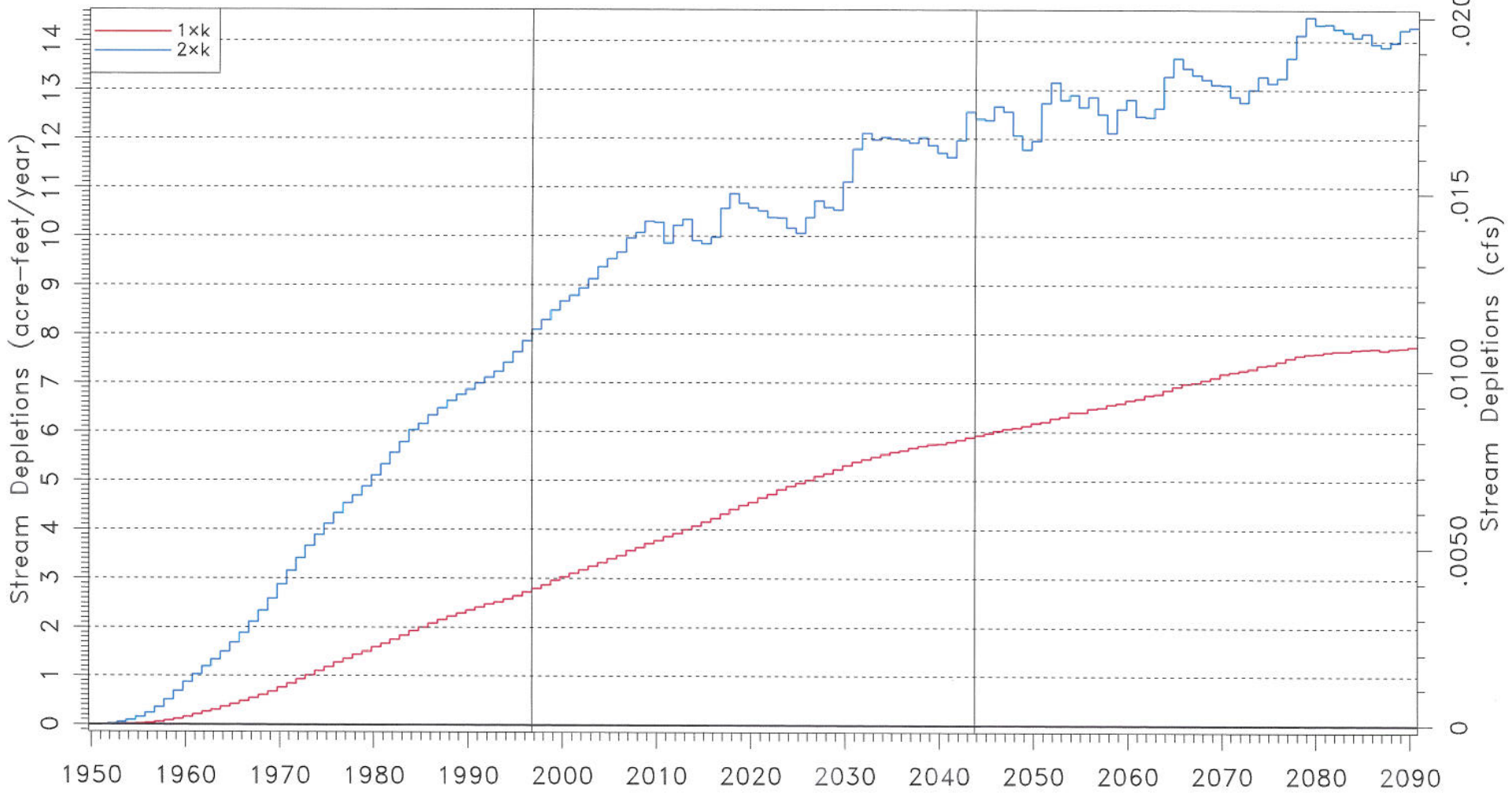


Figure SR-2d.

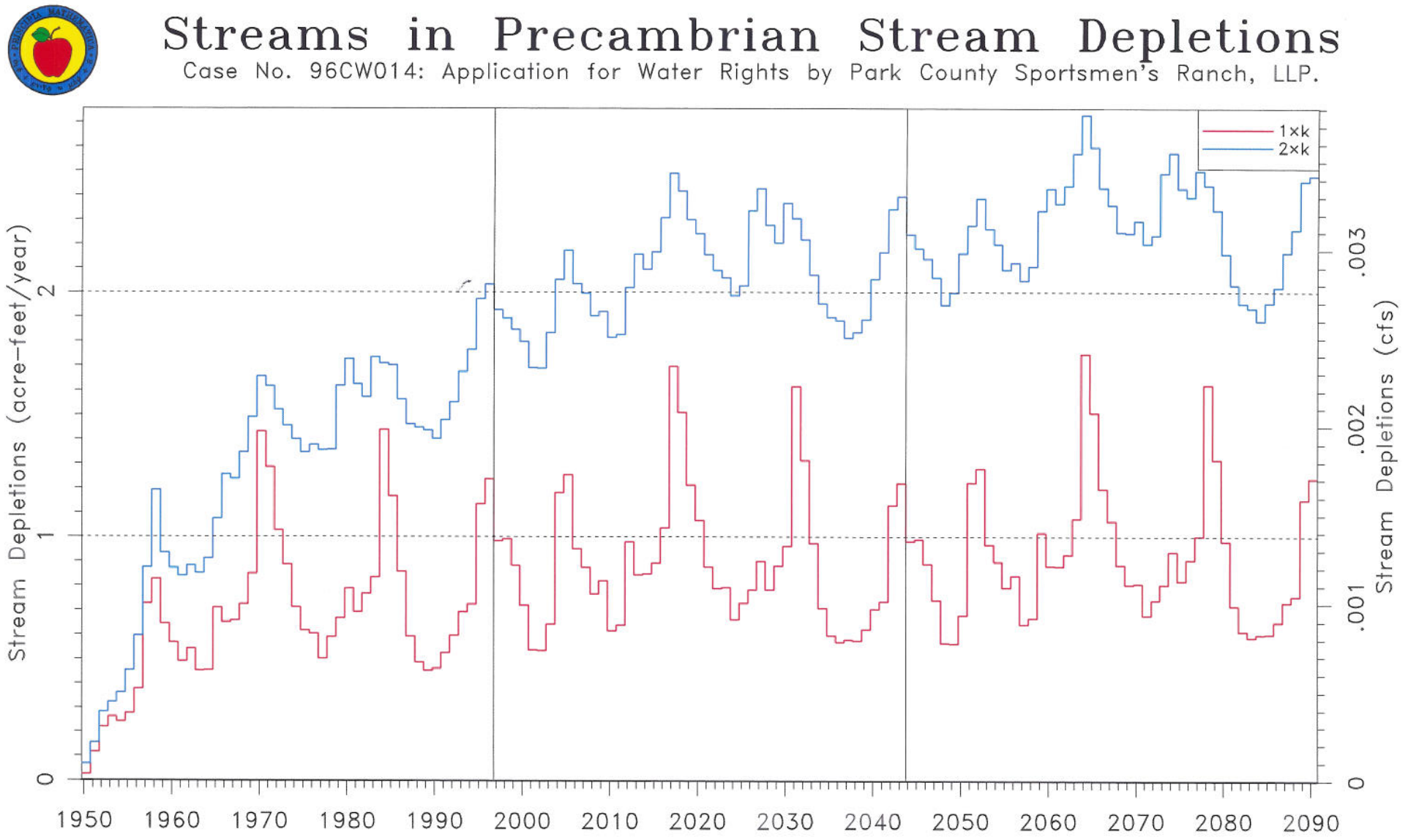

Streams in Precambrian Stream Depletions
Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.
1×k
2×k
Stream Depletions (acre-feet/year)
Stream Depletions (cfs)
0
1
2
.001
.002
.003
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

Figure SR-2e.

Model Salvaged Evapotranspiration

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

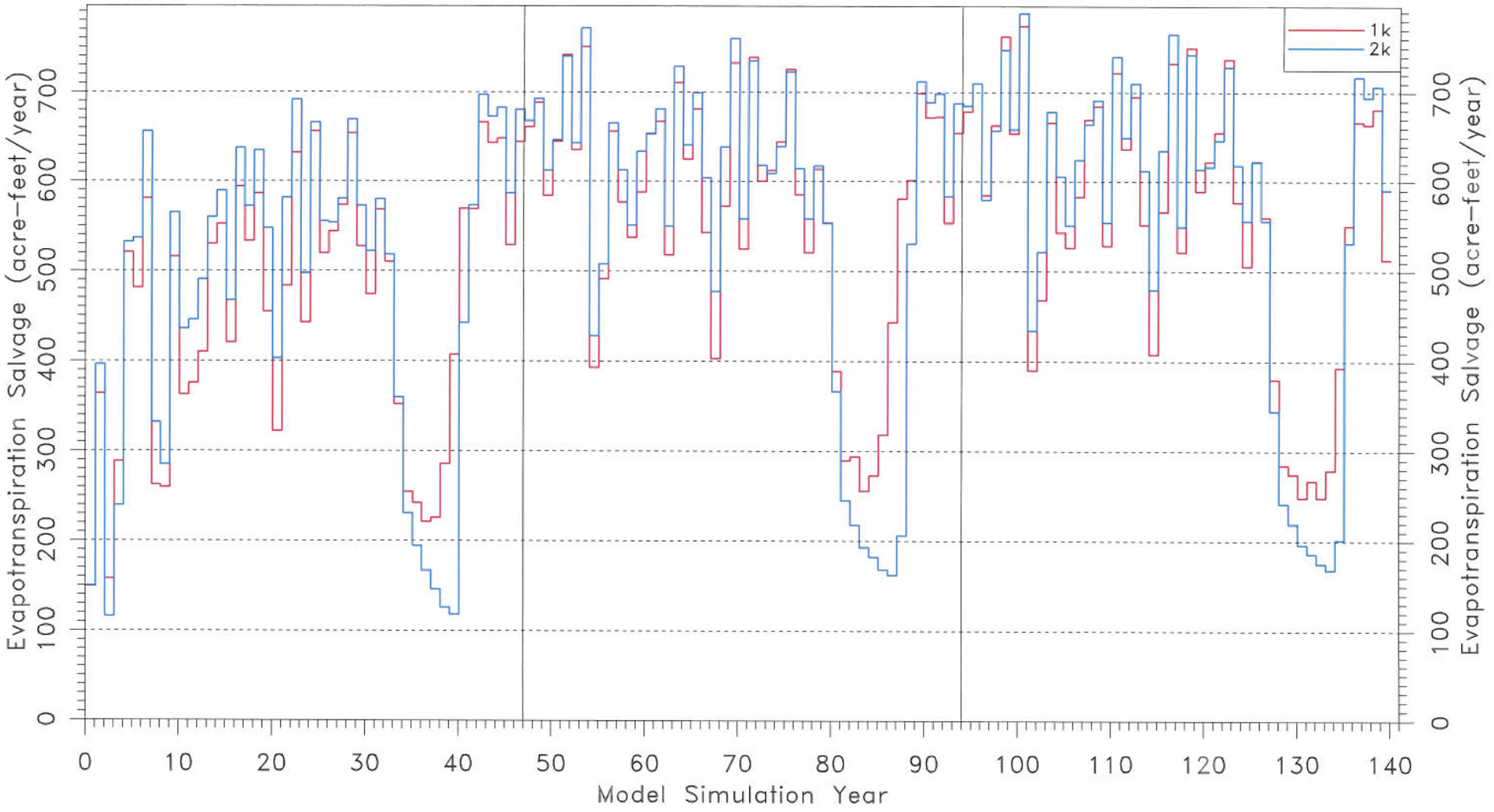


Figure SR-3a.

ET Ground Surface Values

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

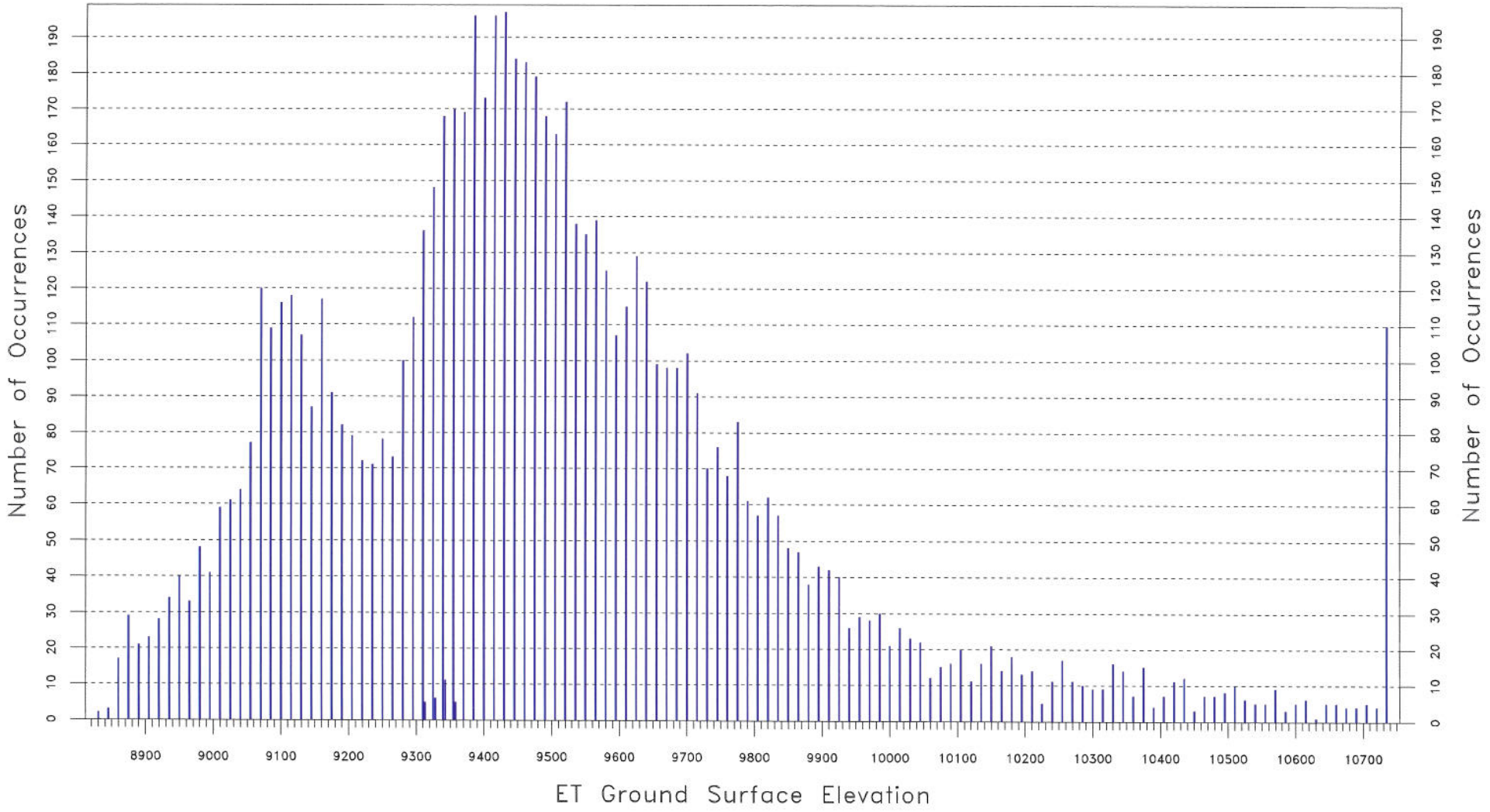


Figure SR–3b.

Recharge Ground Surface Values

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

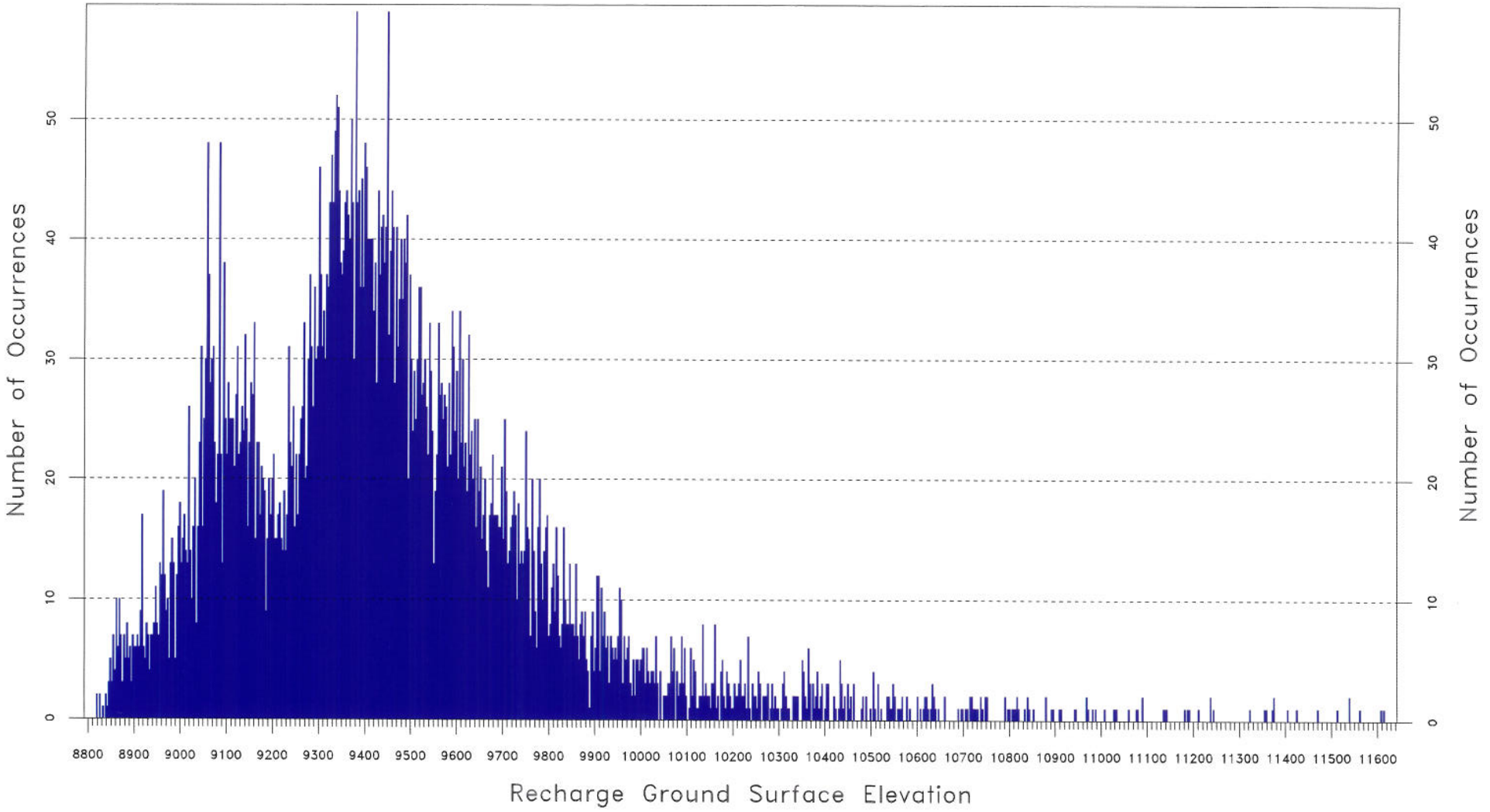


Figure SR–3c.

MODFLOW and Glover Stream Depletions

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

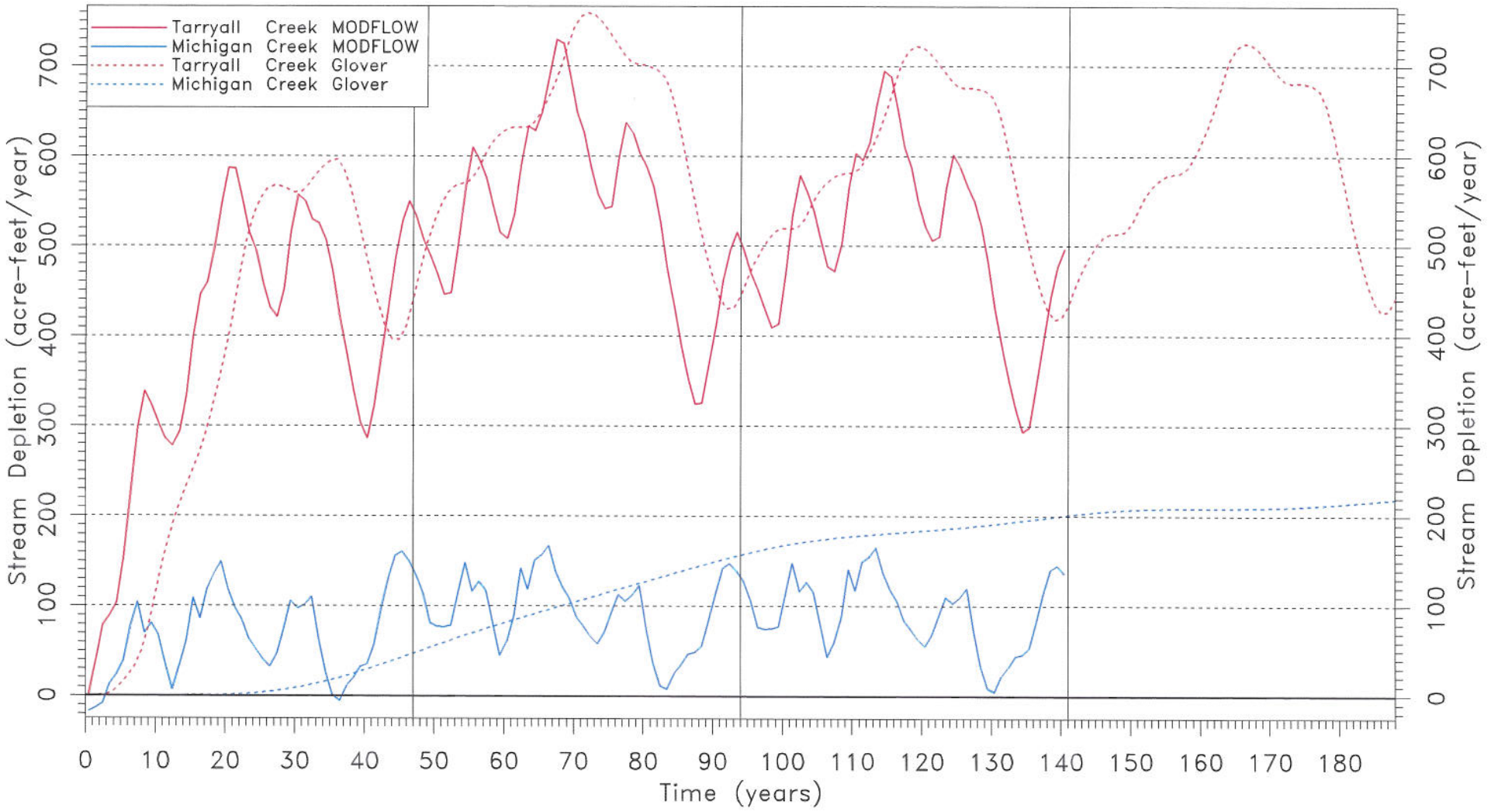


Figure SR-4a.

Glover Sensitivity to Specific Yield

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

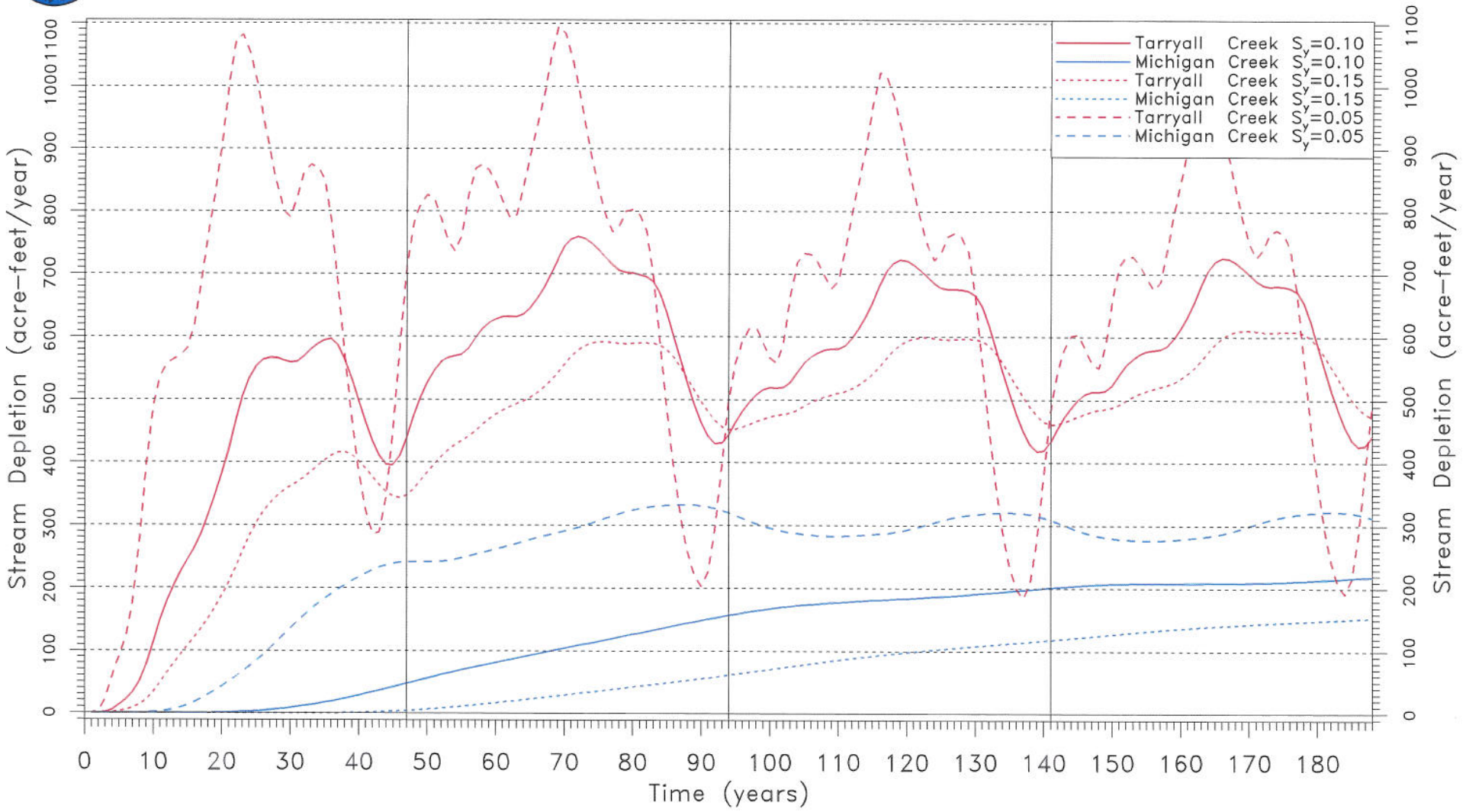


Figure SR-4b.

Glover Sensitivity to Transmissivity

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

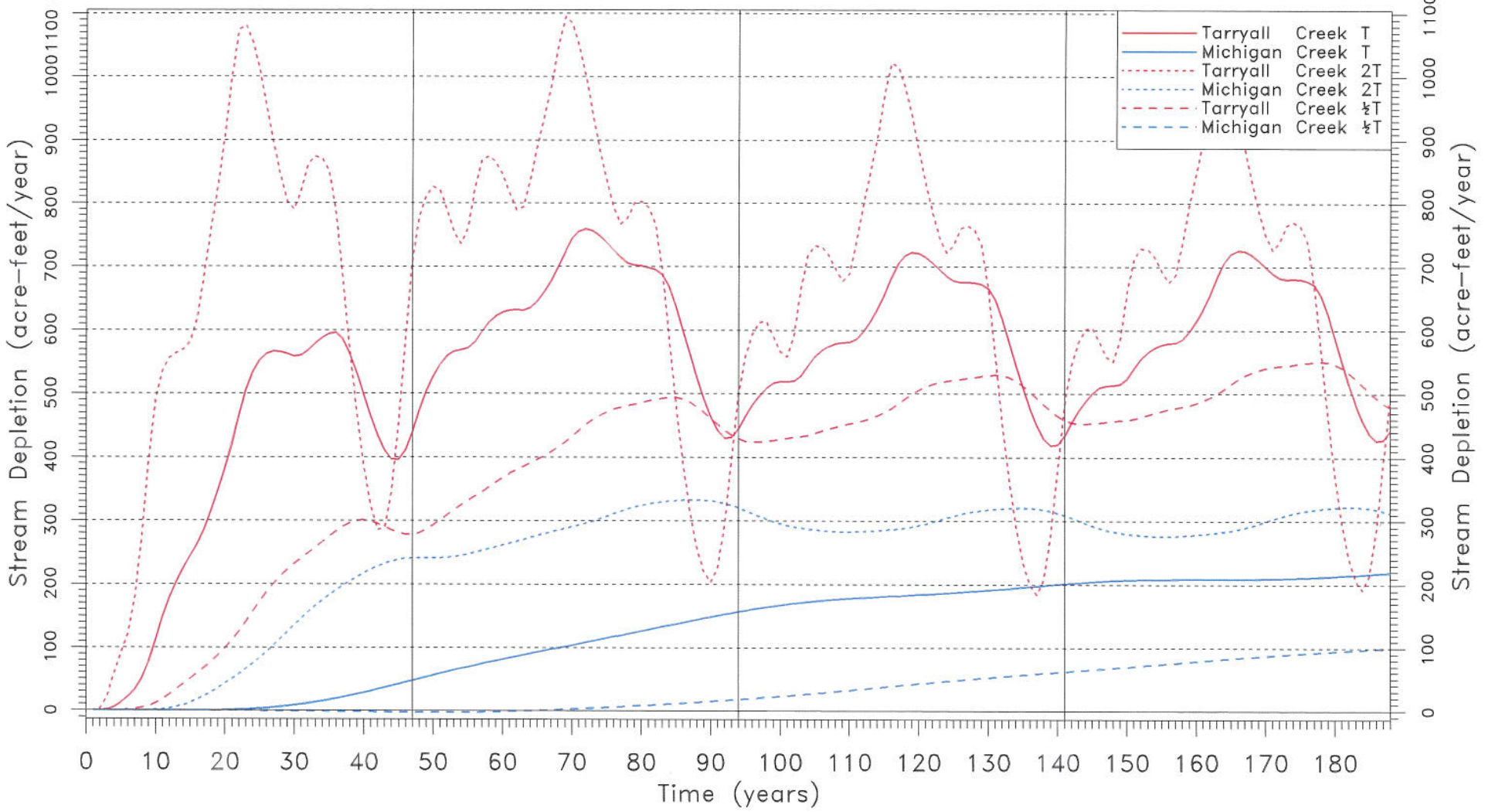


Figure SR-4c.

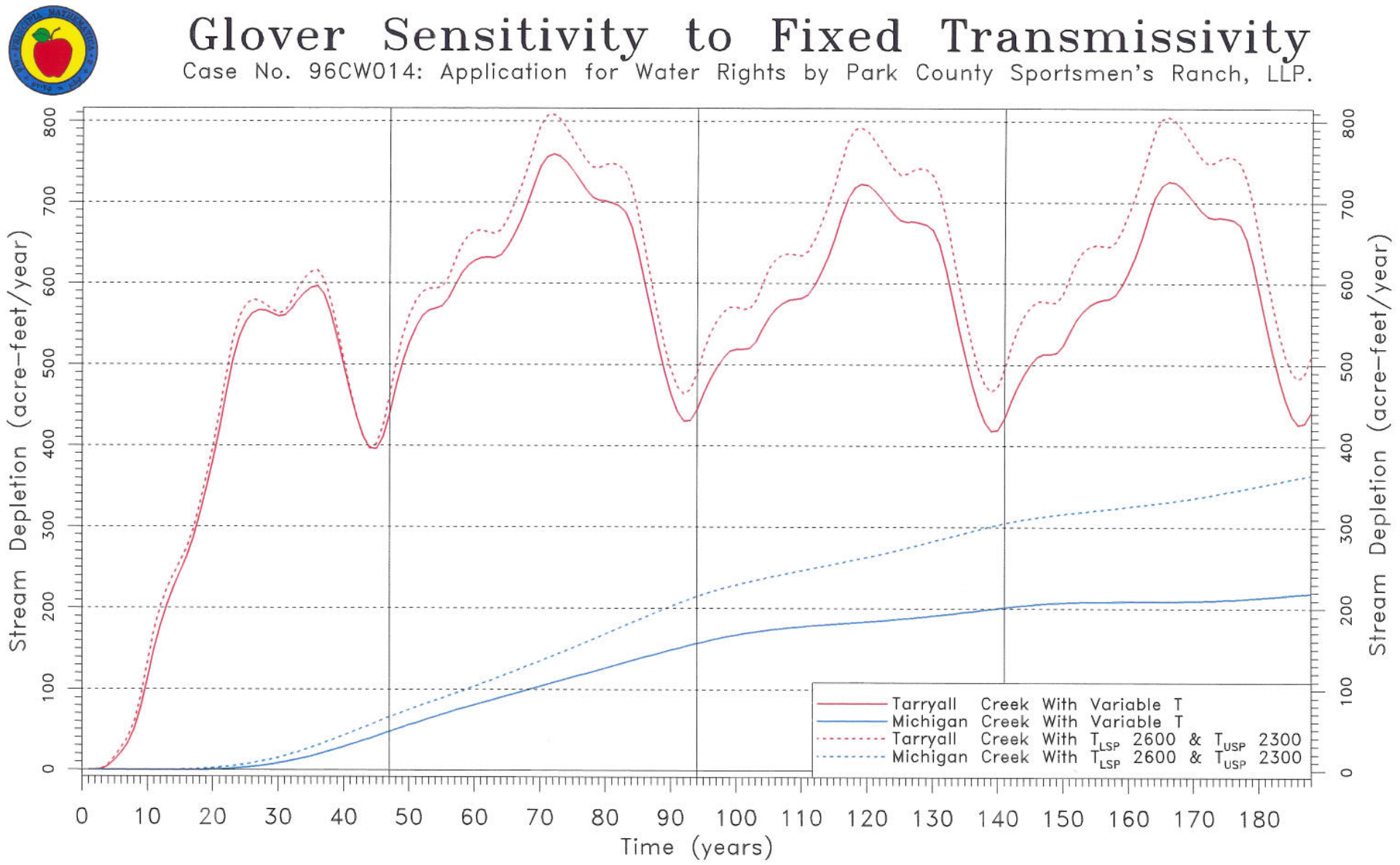

Glover Sensitivity to Fixed Transmissivity
Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.
Stream Depletion (acre-feet/year)
Time (years)
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Tarryall Creek With Variable T
Michigan Creek With Variable T
Tarryall Creek With T_{LSP} 2600 & T_{USP} 2300
Michigan Creek With T_{LSP} 2600 & T_{USP} 2300

Figure SR-4d.

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP

SUPPLEMENTARY
Sur-Rebuttal Analysis of the Applicant's Experts' Rebuttal Opinions

By
Dr. Willem A. Schreüder & Dr. Devraj Sharma
Principia Mathematica Inc.

On Behalf of
The Objectors

July 5, 2000

Table of Contents [1]

[1] *This document represents Principia's SUPPLEMENTARY sur-rebuttal materials based upon evaluations of information produced by the Applicant's experts in support of their rebuttal opinions, as supplemented.*

[2] *Page numbers in this document have been assigned a prefix: 'SSR' denoting the fact that they correspond to Principia's sur-rebuttal findings and opinions.*

List of Supplementary Figures

4.0 SUPPLEMENTARY Sur-Rebuttal Findings/Opinions

Principia received two letter reports dated June 19, 2000 containing supplementary rebuttal opinions of experts for the Applicant by electronic mail on June 20, 2000. One report is *South Park Conjunctive Use Project Supplemental Rebuttal Opinions, Case No. 96CW014* by James L. Jehn, C.P.G. The other is *South Park Conjunctive Use Project Supplemental Rebuttal Opinions, Case No. 96CW014, of Principia Analysis of the SPCUP Computer Model* by Harvey S. Eastman, CPG, PE. The following supplementary sur-rebuttal findings/opinions address issues raised in these reports:

(23) The complexity of the South Park ground water system and the nature of the Applicant's proposed activities within it are such that simpler techniques of analysis, such as the use of the Glover method, cannot be applied to obtain predictions of stream depletions that can be relied upon for water-rights matters such as that involved in this case. Critical assumptions inherent in the Glover method are not met, thus rendering any predictions by the Glover method completely unreliable.

(24) Despite rebuttal claims made by the Applicant's experts, the Applicant's ground water model has never been verified *after* the step of attempting to calibrate the model was undertaken. Just making such attempts to calibrate a model does not render it reliable. The reliability of the model in making predictions as has been done in this case, has therefore not even been evaluated let alone demonstrated.

(25) The Applicant's expert in modelling clearly does not understand the scientific importance, and thus the significance in this case, of either competently undertaking the task of model calibrations or of *independently* verifying that the model can be relied upon.

(26) Despite rebuttal claims to the contrary by the Applicant's modelling expert, the status of model calibrations remains extraordinarily poor. It is a fact that the calibration targets chosen by the expert included wells in which only a *single* water-level measurement had been made. Despite the fact that available measurements represent only instantaneous values of water levels known to fluctuate with time, the expert maintains in rebuttal opinions that he had succeeded in achieving model calibration to steady-state conditions inferred to exist from just one measurement in each well. It is obviously not feasible to derive a valid average water-level distribution based upon such single measurements in wells. The rebuttal claim demonstrates the expert's lack of understanding of the responsibility held by the Applicant to demonstrate model reliability in this case.

(27) The novelty of the Applicant's proposed project and the magnitude of water that is claimed in relation to available resources in the South Park ground water system, even by the Applicant's own estimates, are such as to demand a higher standard of modelling than has

been undertaken by the Applicant. The flow rates of streams in this basin are small enough and the aquifer in contact with them is complex enough that predicting even small impacts, with respect to locations, magnitudes and timings, to them becomes especially significant in this case.

(28) Having been informed by the Objectors' experts that the method of stream routing chosen and implemented by the Applicant's expert in the ground water model had resulted in modelled stream flows being directed uphill, he offers the rebuttal opinion that this somehow does not matters in the **MODFLOW** computer program. Since faithfulness to knowable reality should be at the very center of modelling efforts used to support a significant water-rights application such as that proposed by the Applicant, the lack of even basic understanding by the Applicant's modelling expert is made alarmingly clear by his rebuttal opinion in this respect.

(29) Applicant's experts opine in rebuttal that errors in the representation of historical conditions are of no consequence. Therefore, the unreliability of the Applicant's model calibrations to historical conditions in South Park has been further analyzed by Principia. These historical conditions represented in the NOCUP model runs in fact includes the proposed North Branch Collection System (NBCS) ditch, that is proposed to be constructed in the future. The findings from this analysis are presented in Figures SR-5a and SR-5b. The predicted instantaneous flow rate in the reaches of the NBCS lying between Michigan and Tarryall Creeks, under the various conditions simulated by the Applicant is depicted in Figure SR-5a along with a cameo map indicating the model representation of the NBCS. Several facts become clear in this figure: that the NBCS not only appears in the NOCUP representation of reality prior to its proposed construction, but it also appears in the quasi-steady state (QSS) and transient model calibration conditions; that the predictions for the same reach change even in the historical conditions represented as the QSS, transient and NOCUP; and, that the NBCS acts as a drain carrying captured groundwater during the QSS, transient and NOCUP model simulations made by the Applicant when no such flow should exist. The significance of these entirely unreliable predictions is clarified further in Figure SR-5b which depicts the predicted flow rates in the NBCS, Segment 53, at two reaches; the first shown in red represents Reach-16 which lies approximately midway in the NBCS as represented; and, the second shown in blue represents the terminus reach. The model clearly predicts flows in this non-existent ditch of approximately 35 acre-feet per year under NOCUP conditions and in excess of 200 acre-feet per year under QSS conditions. It thereby conveys ground water from the Michigan Creek ground water sub-basin to the Tarryall Creek sub-basin, when in fact natural ground water flows preclude any such conveyance. The Applicant's model has in fact been 'calibrated' to such unrealistic ground water conveyances.

(30) In rebuttal, Applicant's experts opine that model layering choices do not adversely effect the reliability of the model. The unreliability of the Applicant's model in predicting stream

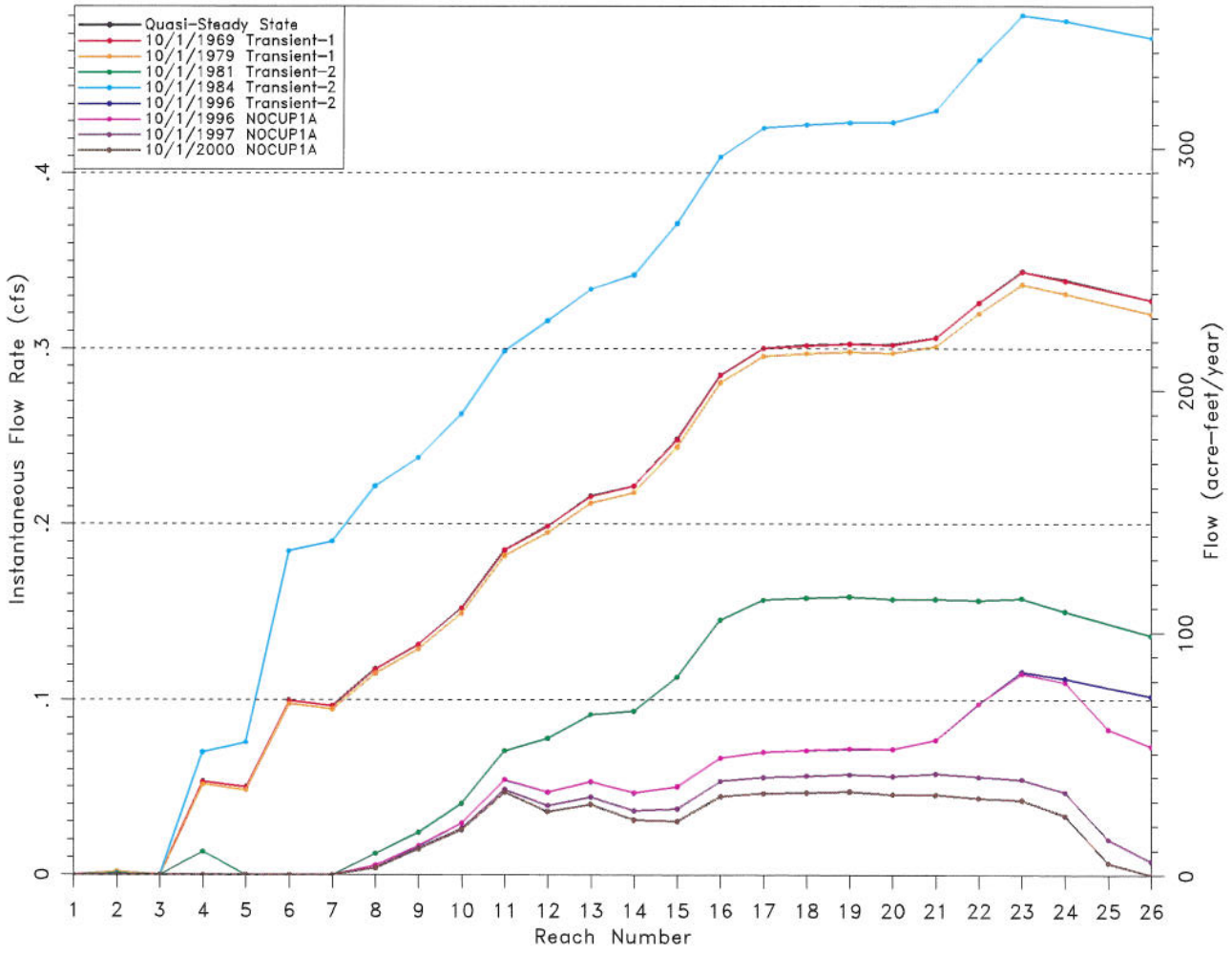
leakage and thus impacts to streams caused by the Applicant's project has therefore been further evaluated by Principia in this context. The findings are illustrated in Figure SR-6 which consists of three hydrograph frames and an associated cameo map of the affected model grid cells. The top hydrograph frame depicts the prescribed stream parameters in a grid cell (27,32) used to represent a portion of Jefferson Creek and the ground water head in layer 1 predicted by the model under NOCUP conditions. The second or middle hydrograph frame depicts the difference between the NOCUP and SPCUP ground water heads predicted by the model at that grid cell, for model layers 1 and 4. It should be noted that the Applicant had chosen to represent layers 2 and 3 as absent below layer 1 in this grid cell, eliminating the possibility of flow between layers 1 and 4 in the model at this location. The bottom hydrograph frame depicts similar information in a nearby grid cell (29,31). From the middle frame, one could infer that the model predicts little or no impact, assessed simply by the subtraction of the NOCUP predicted head from the SPCUP predicted head, both of which are flawed of course. However, the same frame also allows the inference to be made that had the Applicant not deliberately removed model layers 2 and 3 from the grid cell location, the calculated impacts would have been much greater. As shown in the first frame, the difference between the aquifer head and stream stage is about one foot in the NOCUP simulation. A difference of one foot between the NOCUP and SPCUP simulation would therefore double the predicted stream leakage from Jefferson Creek at this location. Clearly, even differences of a fraction of a foot between the NOCUP and SPCUP simulations would significantly alter the predicted leakage from Jefferson Creek at this location. This inference is further substantiated in the bottom frame which demonstrates that an impact in layer 1 of almost a foot is predicted when model layers 2 and 3 are in fact present between layer 1 and layer 4. Therefore, the choices of hydrogeologic representation implemented by the Applicant have thus pre-determined just what the impacts predicted by the model would be to Jefferson Creek.

(31) Notwithstanding the rebuttal opinion offered by the Applicant's modelling expert, Principia's sur-rebuttal analysis indicates that the calculational errors in the procedure employed by the Applicant to estimate depletions to Michigan Creek are, in fact, significant. The findings from this analysis are presented in Figure SR-7. The blue line in this figure denotes the monthly value of stream depletions, defined as the subtraction of the NOCUP stream-aquifer interactions from the corresponding SPCUP values, each of which was previously demonstrated to be flawed, actually predicted by the Applicant's model. The red line in the same figure represents the percentage error in the calculation procedure used which was previously demonstrated to rely upon end-of-month values rather than the instantaneous values actually calculated by the model. These errors have been depicted in a range between +20% and -20%, i.e. within a band of 40%, which is significant. The same type of calculational error effects not only stream depletions, but also other quantities such as evapotranspiration, which are calculated in a similar manner. The error is further propagated

by the surface water model that uses these incorrectly calculated values. The calculational errors are therefore significant.

Flow Along NBCS: Michigan Creek to Tarryall Creek

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.



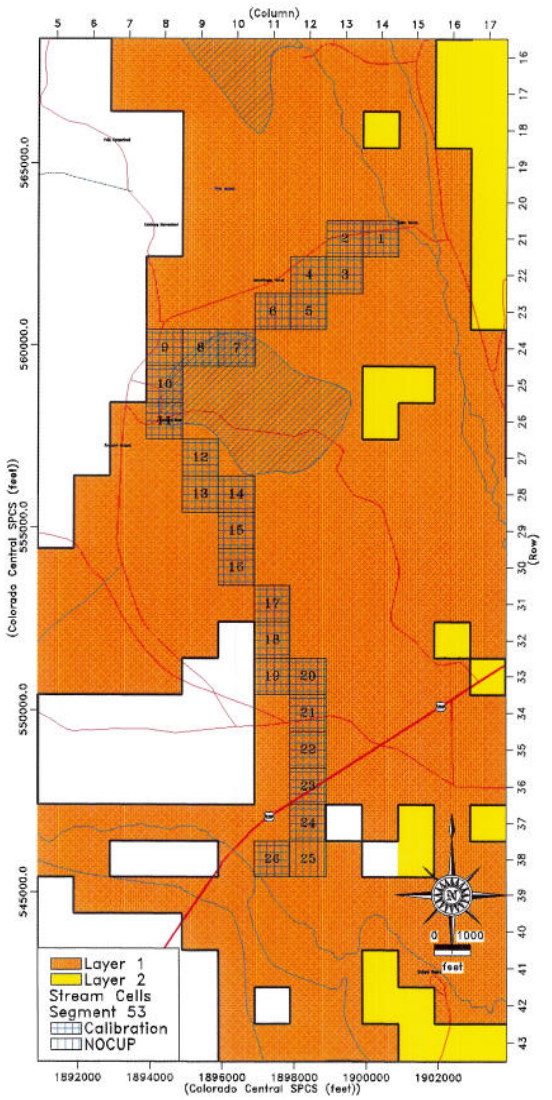


Figure SR-5a.

NBCS Flow: Michigan Creek to Tarryall Creek

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.

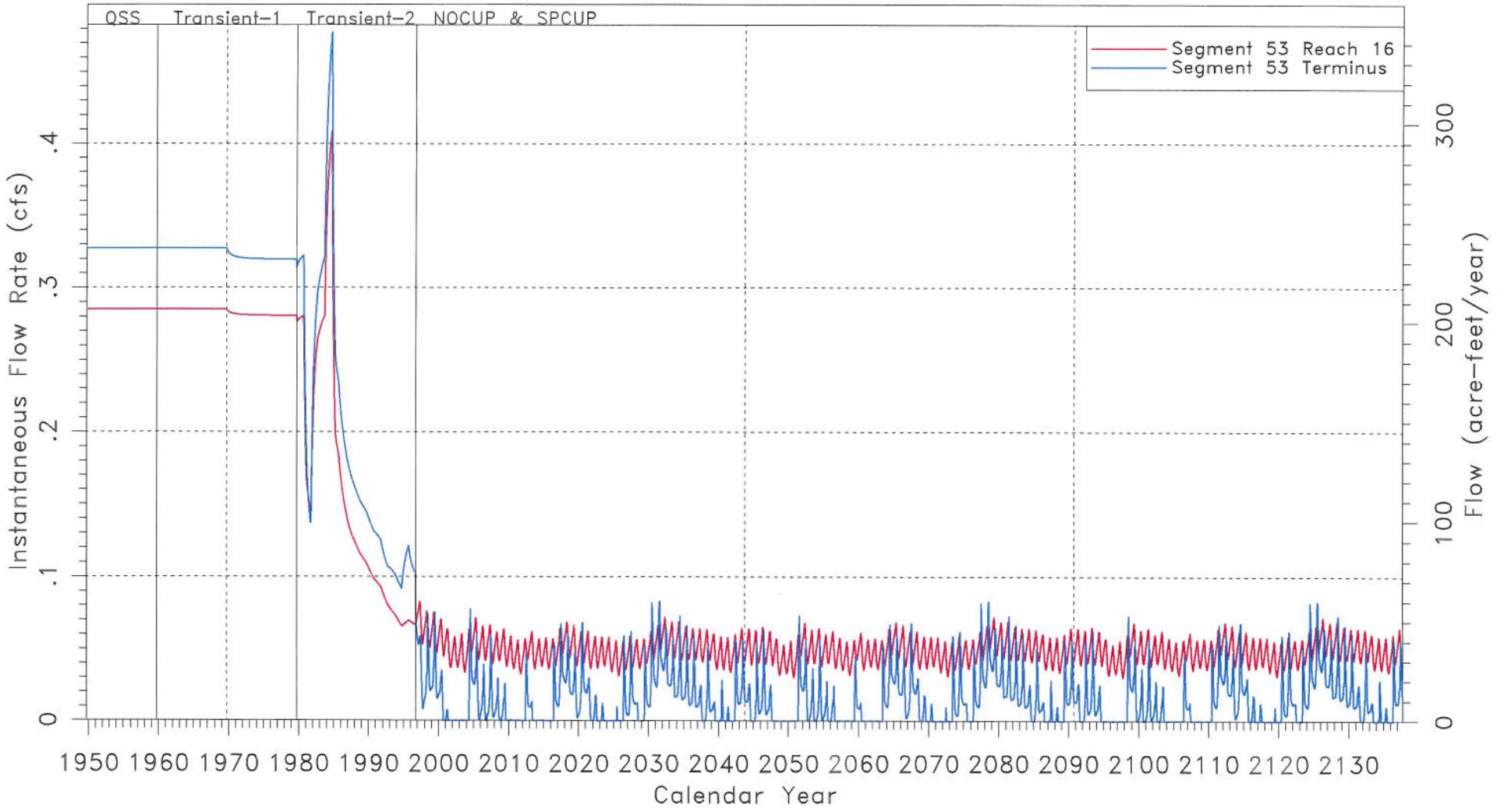
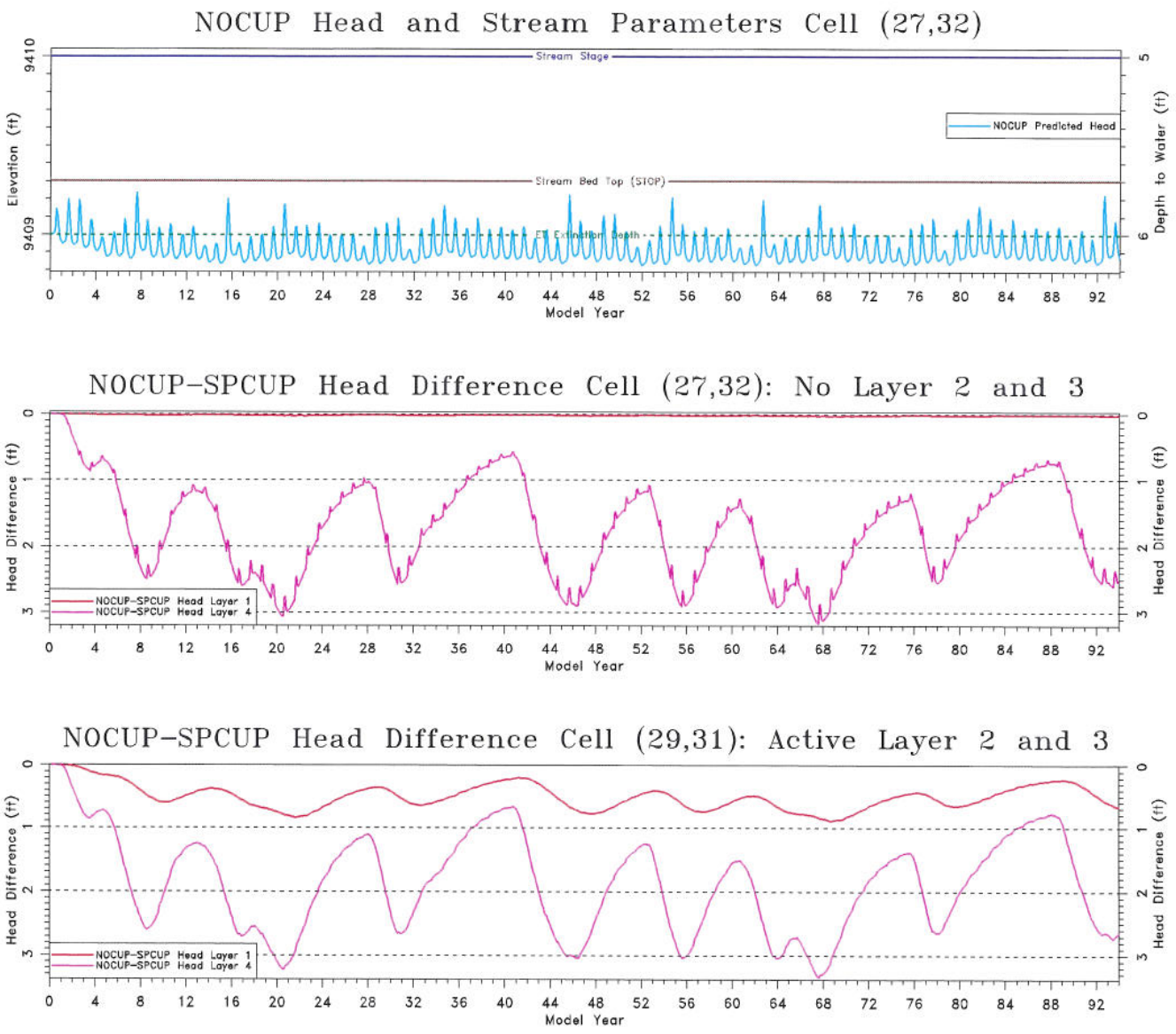


Figure SR-5b.

Jefferson Creek Impacts

Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.



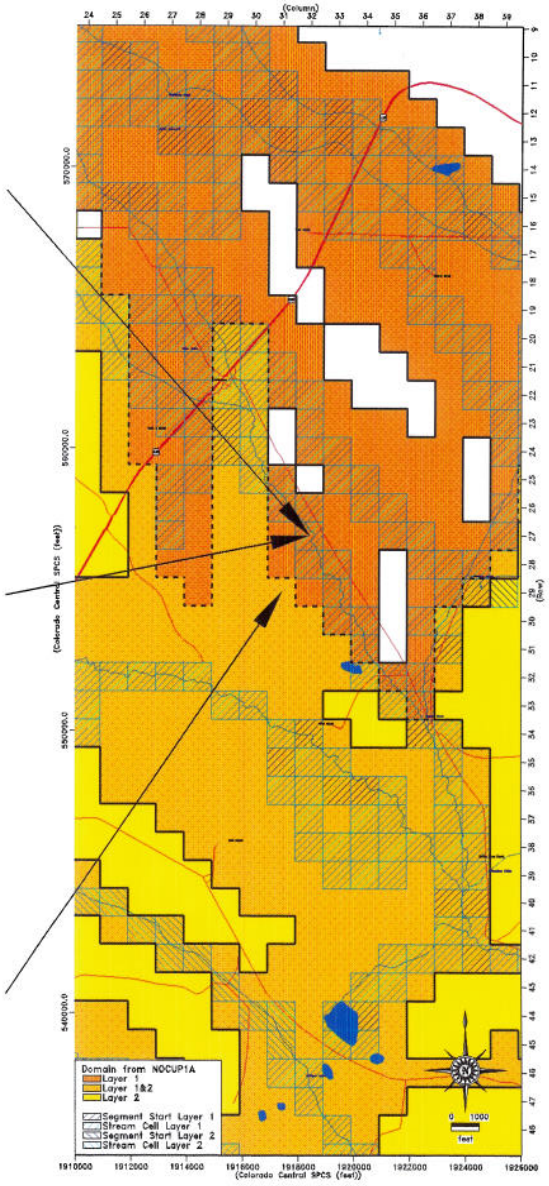


Figure SR-6

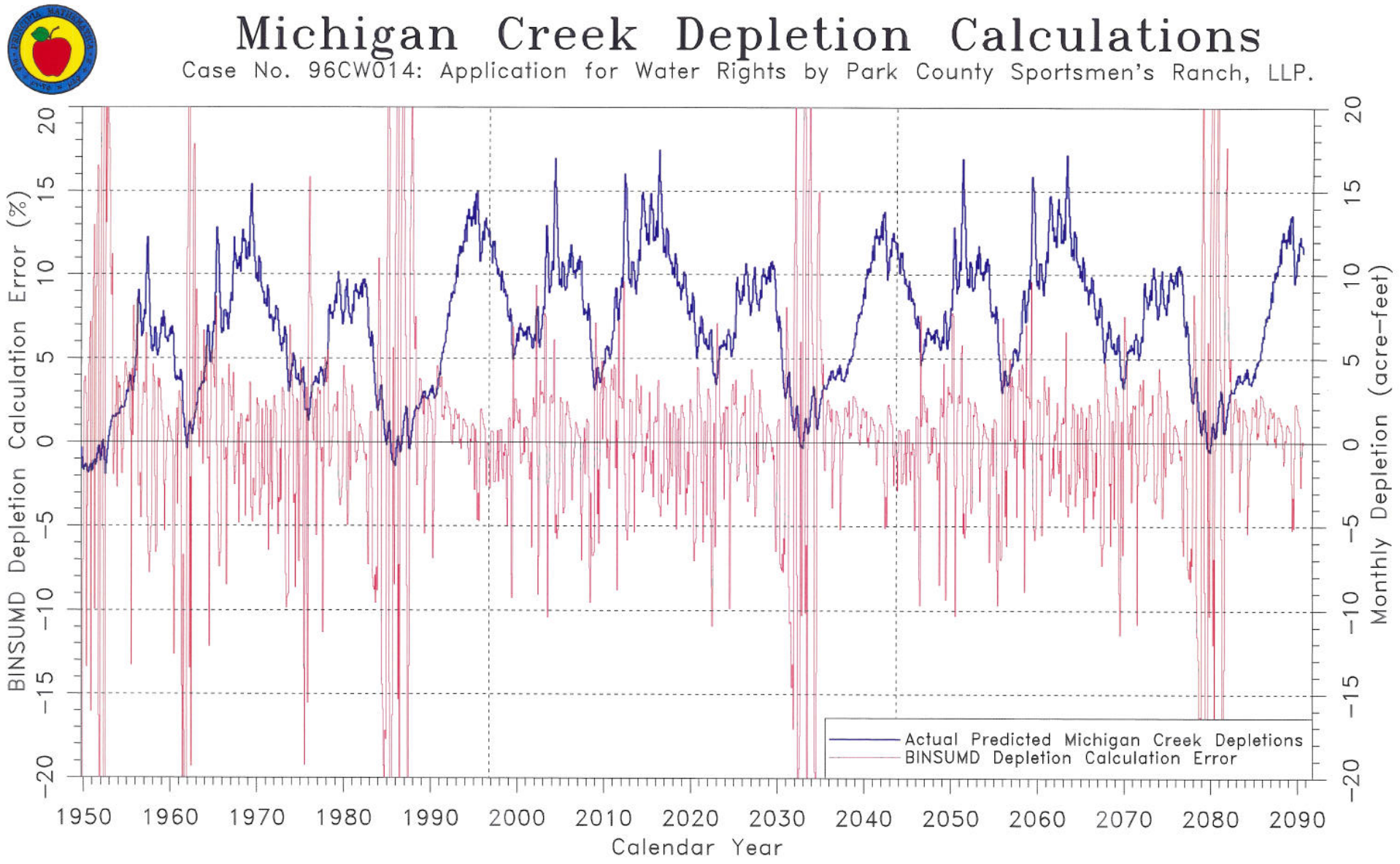

Michigan Creek Depletion Calculations
Case No. 96CW014: Application for Water Rights by Park County Sportsmen's Ranch, LLP.
BINSUMD Depletion Calculation Error (%)
Monthly Depletion (acre-feet)
Calendar Year
Actual Predicted Michigan Creek Depletions
BINSUMD Depletion Calculation Error
20
15
10
5
0
-5
-10
-15
-20
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090

Figure SR-7.