Petroleum Recovery Research Center

a division of New Mexico Tech

Reservoir Evaluation and Advanced Computational Technologies

A Research Group at the New Mexico Petroleum Recovery Research Center

Risk Reduction With a Fuzzy Expert Exploration Tool

DE-AC26-99BC15218

Robert Balch

Acknowledgements

- Co-PI Ron Broadhead.
- Jim Barnes, Project Manager, NPTO.
- Dozens of students.
- Consortium members who have provided data and expertise.

What Risk?

- The FEE Tool study addresses exploration risk, or the estimation of risk that an individual prospect will succeed or fail, prior to drilling.

Why and How?

- Incomplete and sparse information increase risk for oil exploration and development projects.
- As smaller companies and tighter exploration budgets increasingly predominate in the onshore U.S., storing and accessing expert knowledge becomes increasingly important.
- Expert Systems can fill this role.

FEE Tool Goals

- The FEE Tool project was designed to test the ability of an expert system to mimic the logical processes of human Explorationist's.
- Two Plays in New Mexico were selected to evaluate the ability of the software:
  - Lower Brushy Canyon (Delaware Sands)
  - Siluro-Devonian Carbonates

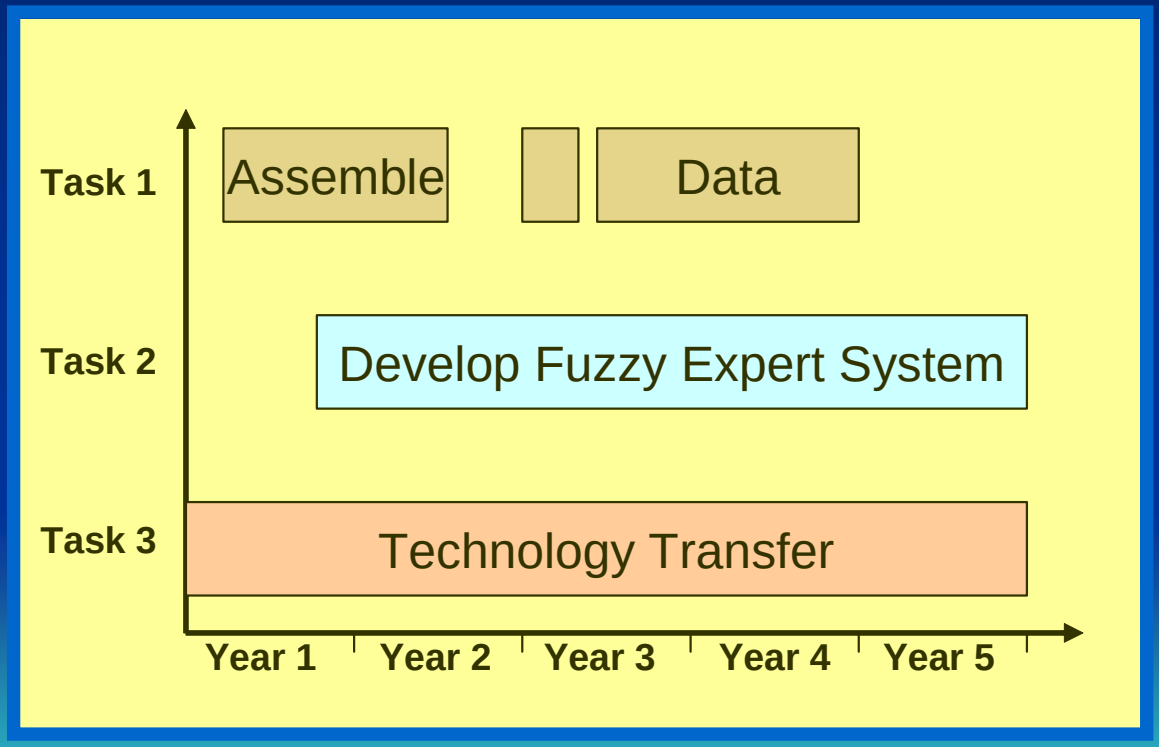
Portability

- A concern in generating software that will be utilized by a wide variety of companies is the portability of software and machine requirements.
- We used Java, a platform independent programming language, to allow the software to run on our servers, while being accessible to anyone with an internet capable computer and browser.

Project Status

Tasks

- The project ran for 72 months. A no-cost extension added features and Tech-transfer.



Task 1: Assemble Data

- A large database of public domain information was compiled for both the Brushy Canyon and Devonian plays:
  - Production Data
  - Well and pool locations
  - Regional geophysical data
- Additional data was generated by the project:
  - Geologic maps from well tops and core analyses
  - Digital well logs
  - Attribute and predictive maps

Task 1: Assemble Data

- A Knowledgebase was collected and collated from a wide variety of sources for both plays:
  - Expert knowledge was gained from interviewing Explorationist's
  - Literature searches
  - From analysis of trends in the data.

Task 2: Develop the Fuzzy Expert System

- All required data and knowledge resides in network accessible databases for each play.
- Crisp models were developed and tested for each play using rules in the knowledgebase.
- A GUI for the fuzzy inference engine was developed using specific rules for each play.
- Both system have been tested and are available on the web:
  - HTTP://ford.nmt.edu

Task 3: Technology Transfer

- The project has generated 47 papers and presentations and more than a dozen technical reports and 11 graduate theses and dissertations. Two training workshops, gave users hands-on experience with the Expert System software.
- Companies of all sizes are interested in project results, and to date we have transferred project results directly to six oil companies, and trained workers from a score of other companies.

Task 3: Technology Transfer

- Tech transfer will continue after the end of the project:
  - Publication in peer reviewed journals
  - Completion of graduate degrees and
  - Via REACT web pages

Deliverables

- Annual and Semi-annual reports to DOE.
- Final compilation of all data and developed software to DOE:
  - Final Report submitted
- Availability of software in an interactive format on the web to producers of all sizes:
  - Delaware Basin FEE Tool
  - Devonian Carbonate FEE Tool
  - Supplementary software
    - PredictOnline and FuzzyRank

Deliverables For Extension

- Users desired several changes to the software beyond the original specifications:
  - Stand-alone versions
  - Batch mode
  - Availability of raw project data (WDMS)
- Additional tech transfer opportunities were also utilized.

Milestones

- August 27 2003
  - Release of Brushy Canyon FEE Tool to consortium for beta testing
- February 2004
  - Release of Devonian FEE Tool to consortium for beta testing
- March 14 2004
  - Release of all software for public use online.
- March 14 2005
  - Stand-alone software delivered
    - Web Distribution
    - CD distributable by DOE
    - All software in the public domain

Un-Discussed/Collateral Work

- Generation of dozens of geologic maps and cross-sections and useful interpretations.
- Generation of regional geophysical attributes.
- Regional log correlations to Bulk Volume Oil.
- Digitization of hundreds of Brushy Canyon wire-line logs.
- Neural Network time-to-depth conversion using seismic attributes.

Un-Discussed/Collateral Work

- Neural Network generated maps of regional expected production.
- Online neural network software (PredictOnline).
- Online software to rank non-linear attributes for suitability of correlation (FuzzyRank).
- An online database of project data/results, useful alone or as a supplement to the FEE Tool software.

Expert Systems

Definitions

- Expert System - "An intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions" (Feigenbaum 82).
- Crisp Inference Procedures – Inference procedures that use crisp rather than fuzzy sets.
  - "an object is either in a set or not in a set" (Giarratano 98)

Definitions

- Knowledge Base - A collection of facts, relations, procedures etc., which constitute the knowledge about a particular domain" (Hart, 1986): In this context the knowledge base is where the expert rules are stored.
- Answer Base – A collection of data and results from the rules in the knowledge base used as inputs in the inference engine.

What is an Expert System?

- We define an Expert System as an artificial intelligence tool which stores expert opinions and methods of analysis.
- An expert opinion, or *rule*, would be something like "High porosity is favorable for high production".
- These Rules are stored in a knowledgebase or more simply a database of expert opinions.

But this is a Fuzzy Expert System...

- A fuzzy expert system is an expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data.
- We use fuzzy logic to more accurately model the incomplete and sparse data we are often confronted with when making decisions:
  - Allows error ranges to be factored in
  - Moderates the effect of spurious data

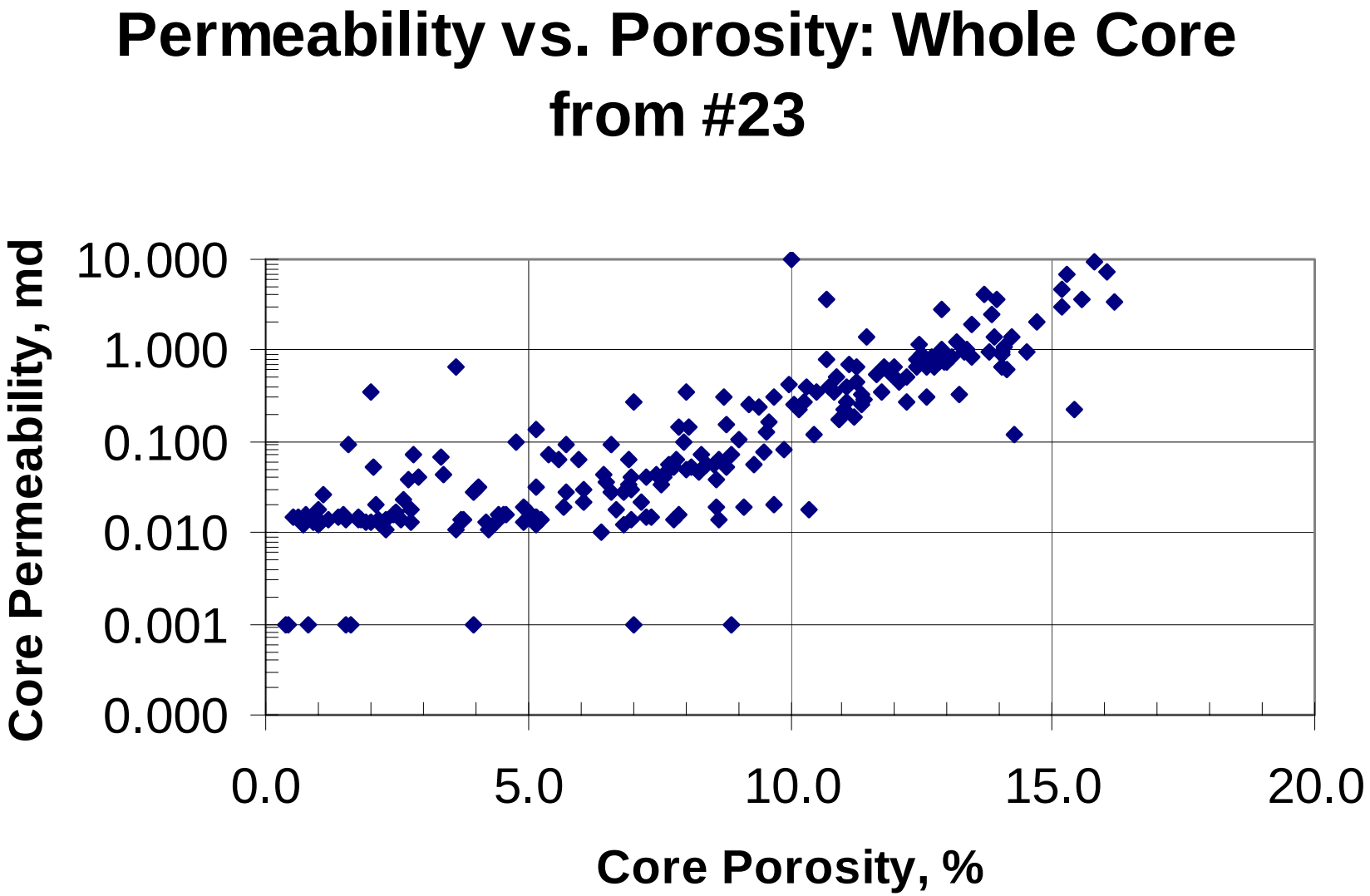
Storage of Human Knowledge

One of the goals of the *expert system* and *knowledge base* is to preserve expert knowledge. This helps to prevent information from being lost when experts move on to different projects or leave the field entirely as well as making their knowledge more portable and accessible.

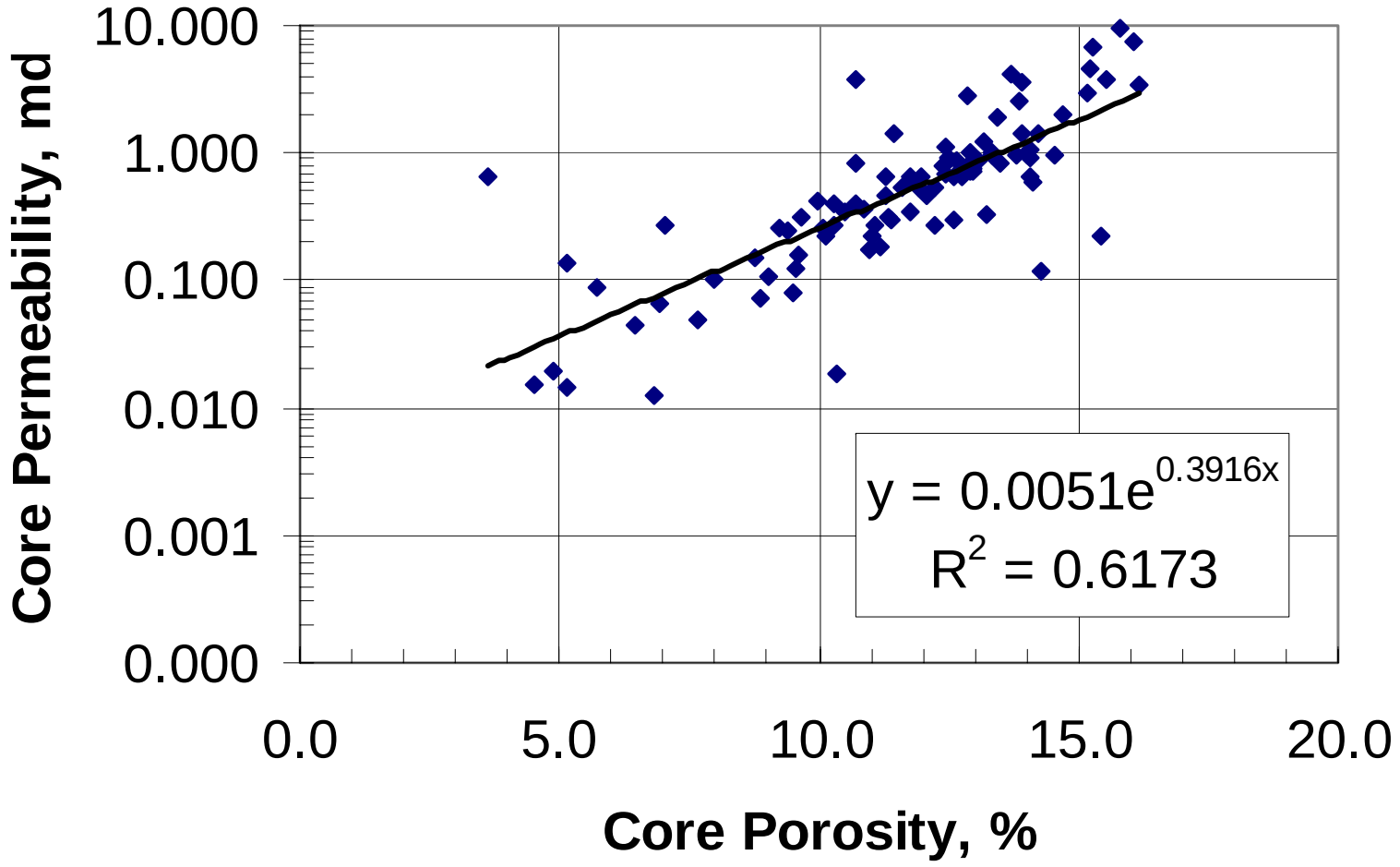
Crisp vs. Fuzzy Definitions

- An important concept for inference engine development is the difference between crisp and fuzzy definitions, because much of the data used in prospect evaluation is inherently fuzzy.
- A crisp definition is defined here as a numerical value that is known precisely, such as “Porosity = 10.215%.”
- A fuzzy definition on the other hand is defined more loosely using linguistic variables and/or fuzzy membership sets, such as “porosity is moderate.”

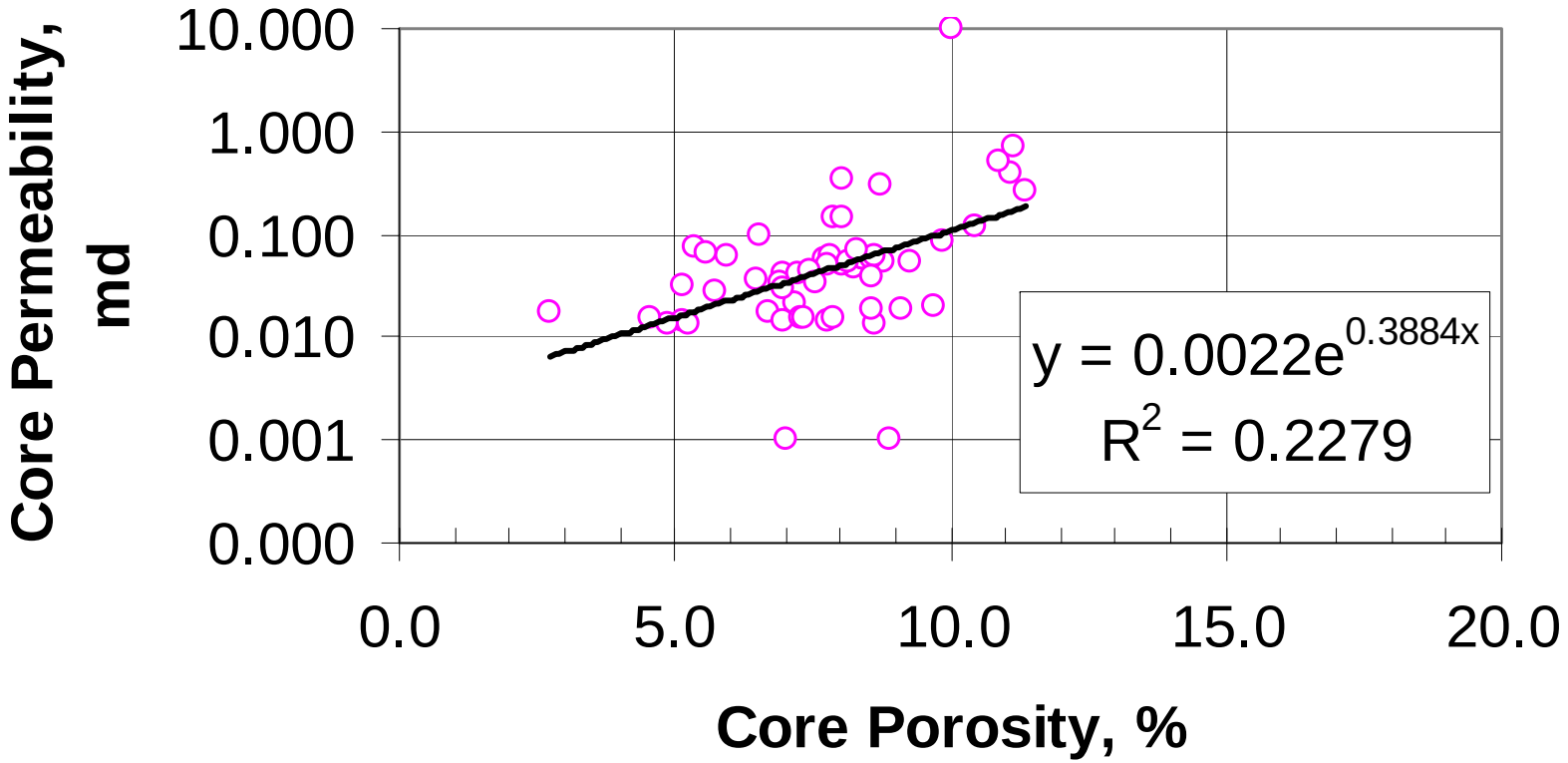
Example 1: Local Data



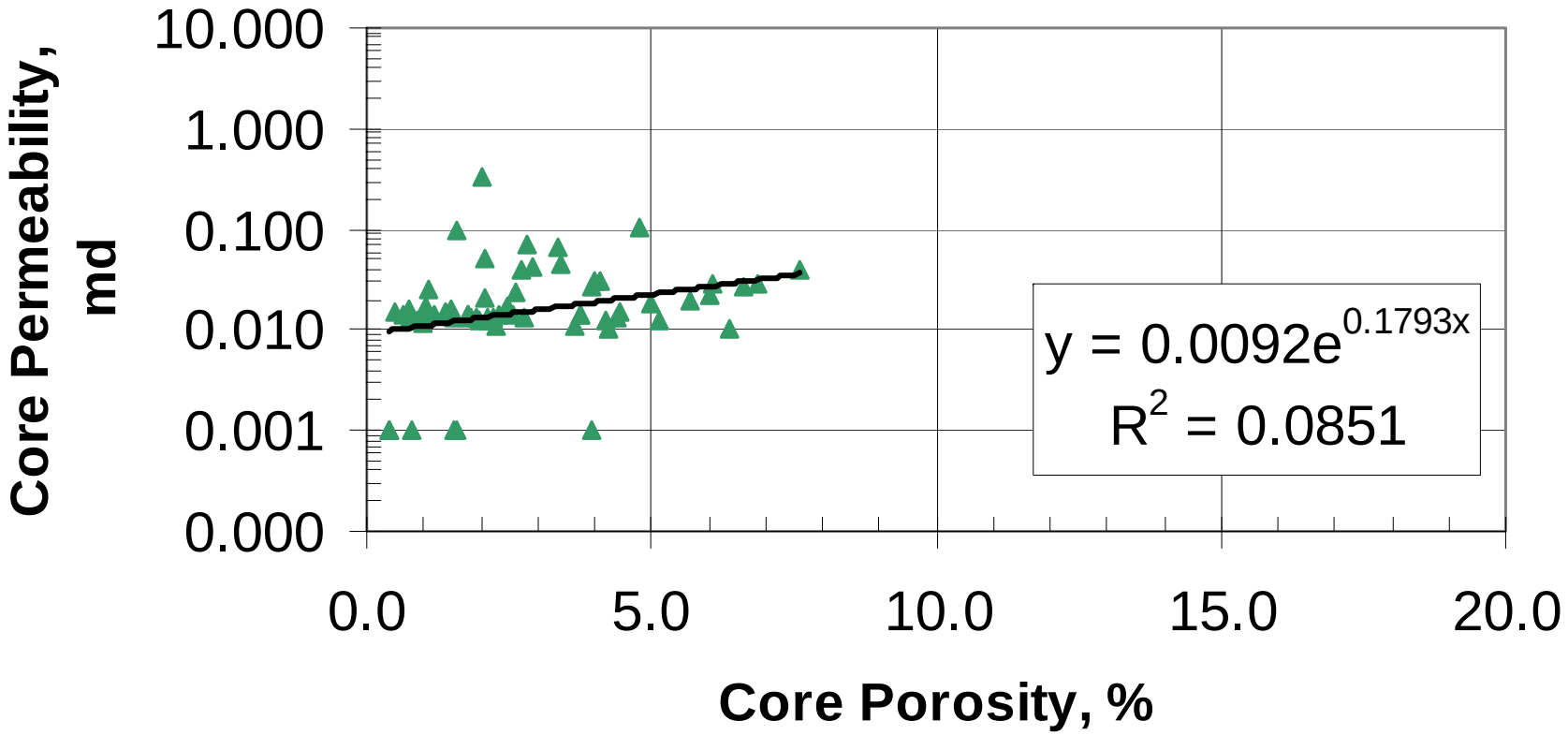
Permeability vs. Porosity: Sandstone only



Permeability vs. Porosity: Laminated Sandstone only



Permeability vs. Porosity: Calcite, Shale, and Limestone



Example 1: Crisp Rules

IF it is sandstone THEN

$$K = 0.0051\exp(0.3916\Phi)$$

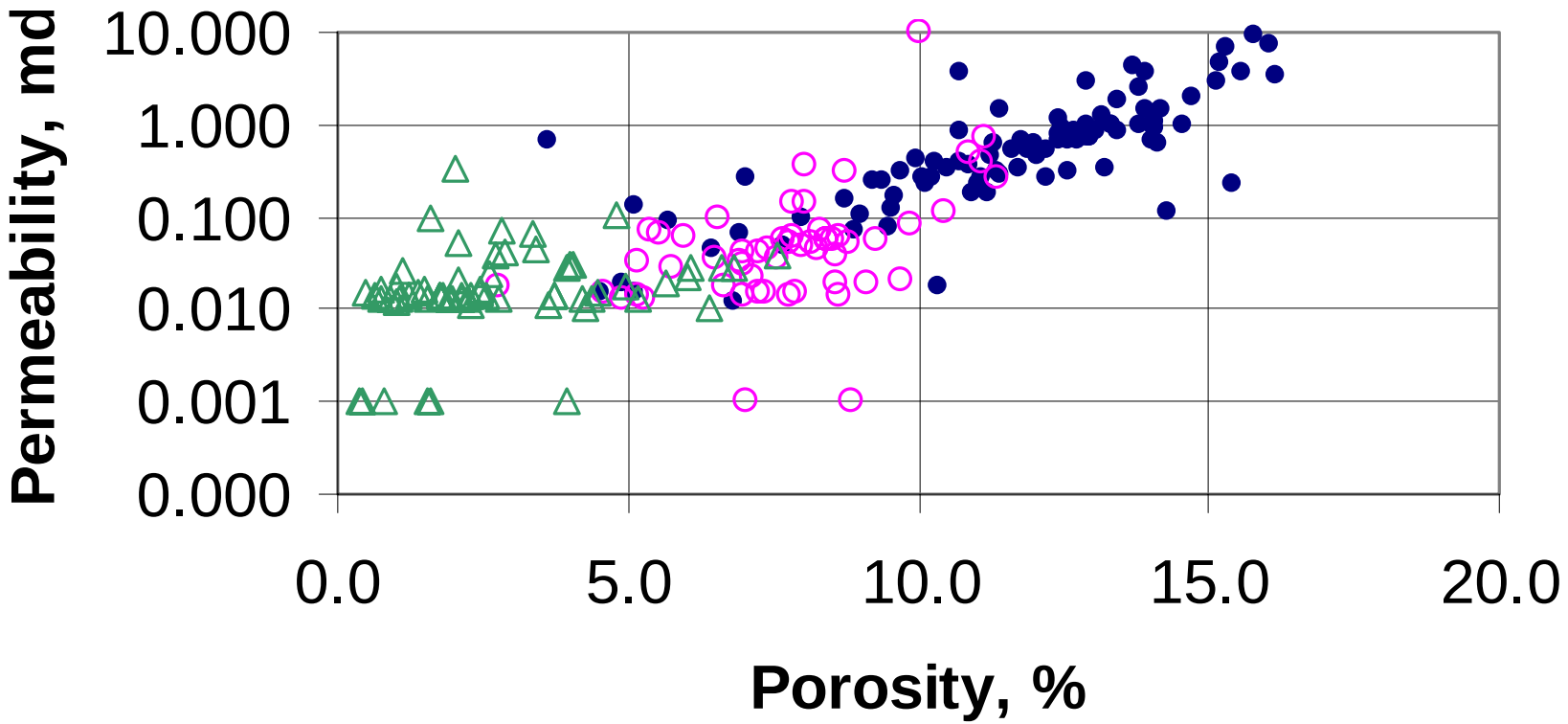
IF it is laminated sandstone THEN

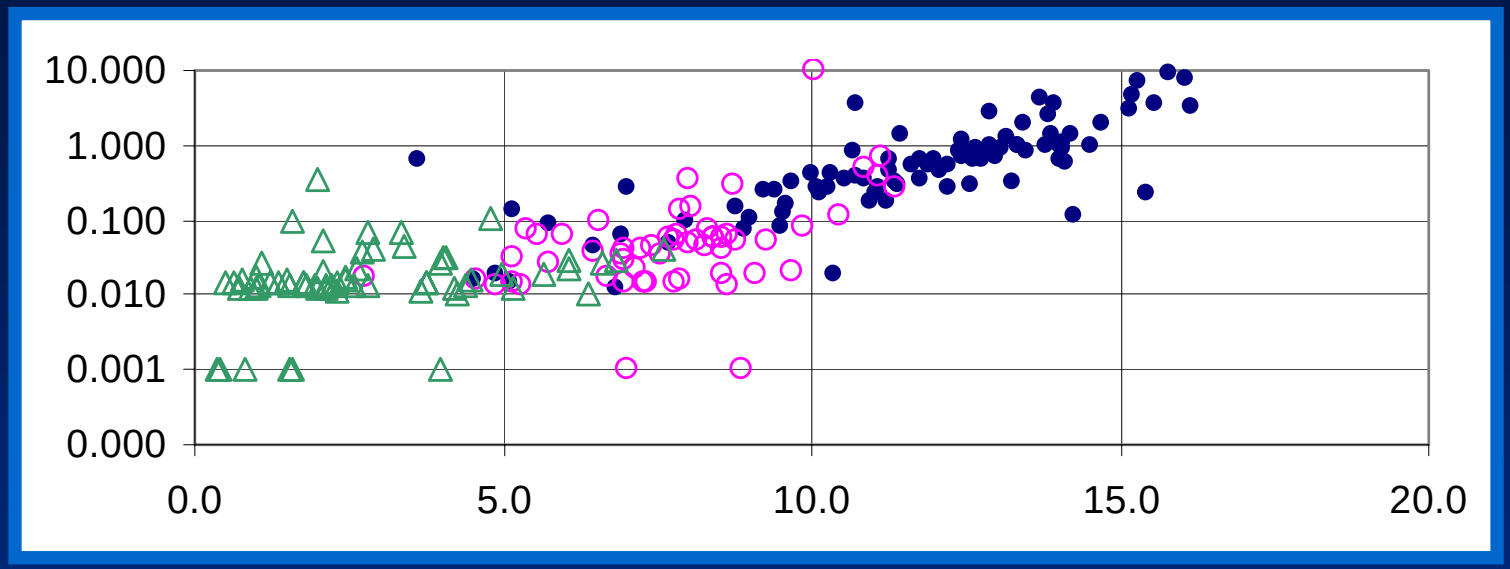
$$K = 0.0022\exp(0.3884\Phi)$$

IF it is calcite, shale, or limestone THEN

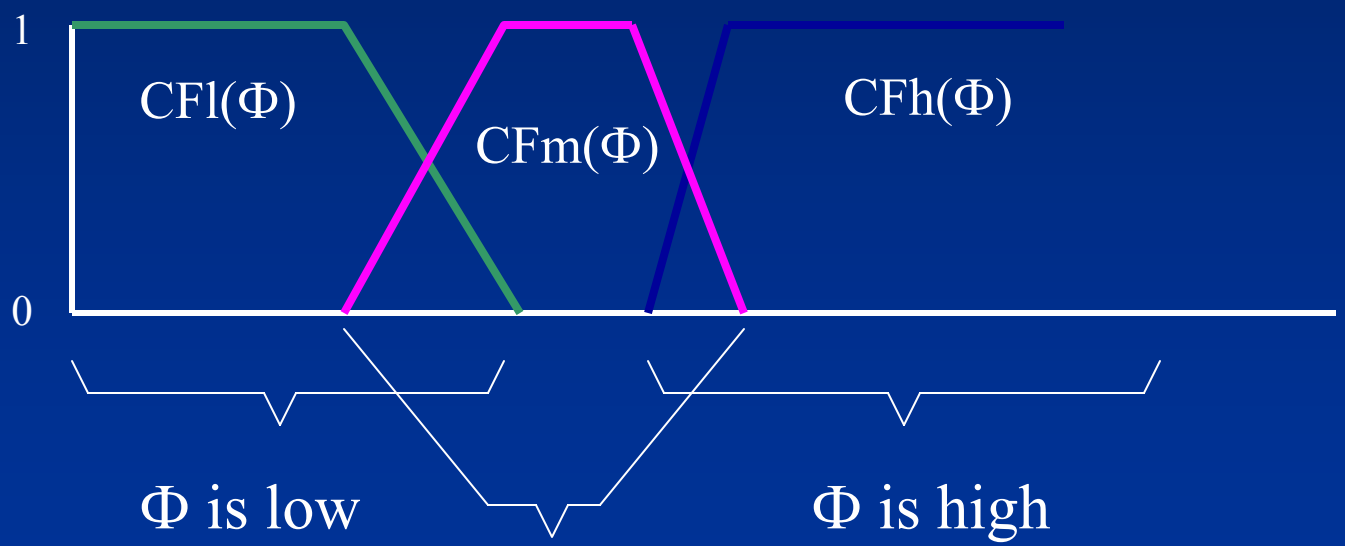
$$K = 0.0851\exp(0.1793\Phi)$$

Permeability vs. Porosity: Sorted





Certainty Function



Fuzzy Variable:

Example 1: Fuzzy Rules

Given $\Phi = 0.1$ then Φ is in the set of "porosity is high" and also belongs to the set of "porosity is medium"

IF Φ is high with a certainty of $CFh(\Phi)$

AND

Φ is medium with a certainty of $CFm(\Phi)$

THEN

$$K = CFh(\Phi) * 0.0051 \exp(0.3916\Phi) + CFm(\Phi) * 0.0022 \exp(0.3884\Phi)$$

Example 2: Regional Data

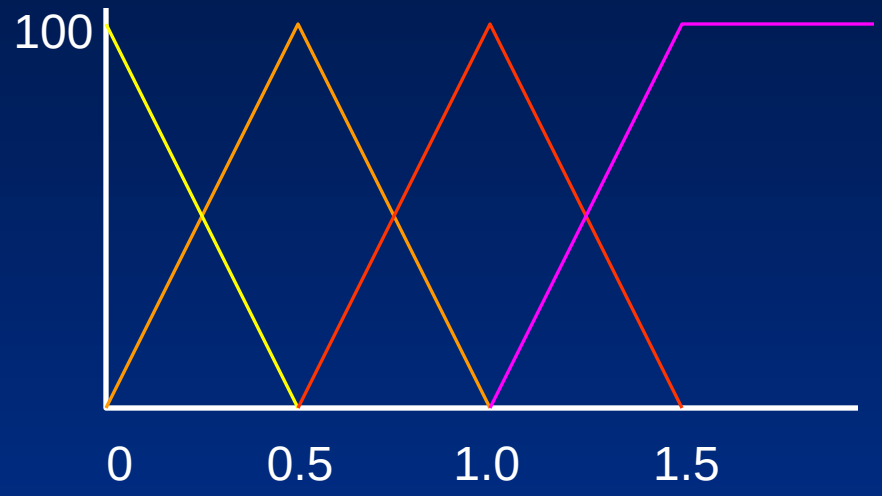
- In exploration, relevant data such as porosity is sometimes approximated or interpolated from data collected at nearby wells.
- The following is a simple example of how principles of fuzzy set theory can be used, along with expert opinions, to compute a value for a well's potential based on just two factors:
  - Porosity
  - Total Organic Carbon

Rules – Expert Knowledge

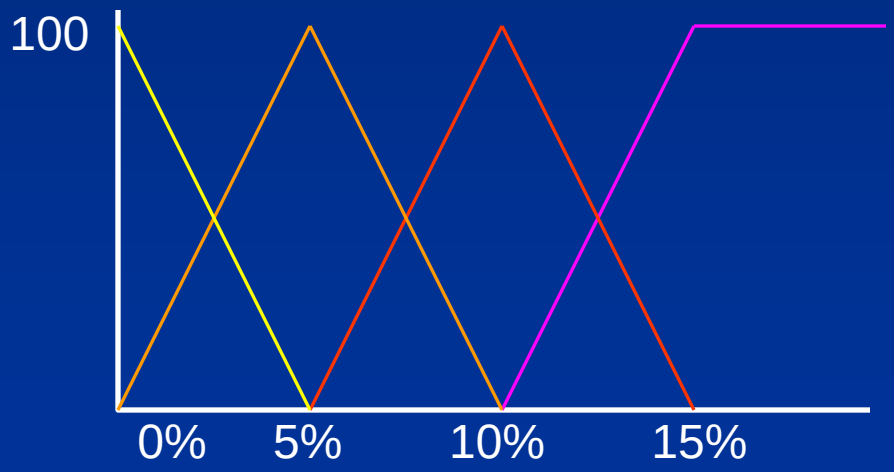
1) If T is zero then R is zero
2) If Φ is zero then R is zero
3) If T is low and Φ is low or medium, then R is low
4) If T is low and Φ is high then R is medium
5) If T is medium and Φ is low then R is low
6) If T is medium and Φ is medium or high, then R is medium
7) If T is high and Φ is low or medium then R is medium
8) If T is high and Φ is high then R is high

Definitions and Fuzzy Sets

- T=Total Organic Carbon
  - T: ZERO if $0 \leq T < 0.5$
  - T: LOW if $0.5 \leq T < 1.0$
  - T: MEDIUM if $1.0 \leq T < 1.5$
  - T: HIGH if $1.5 \leq T$

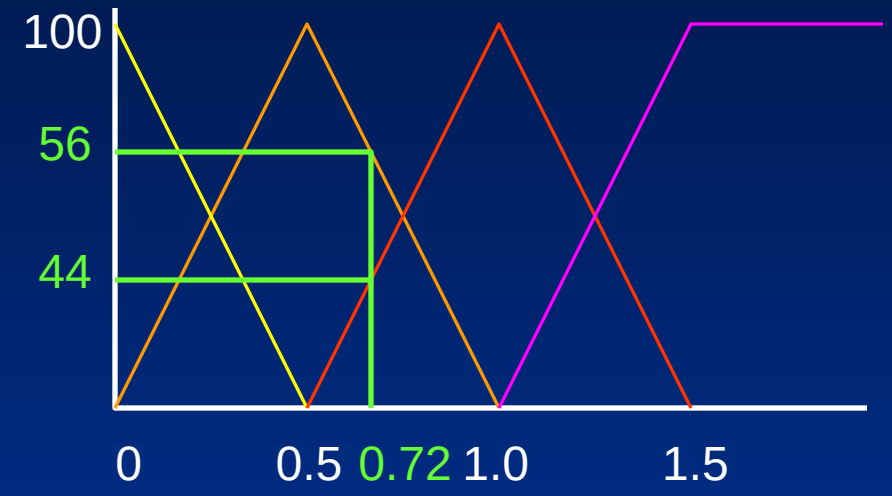


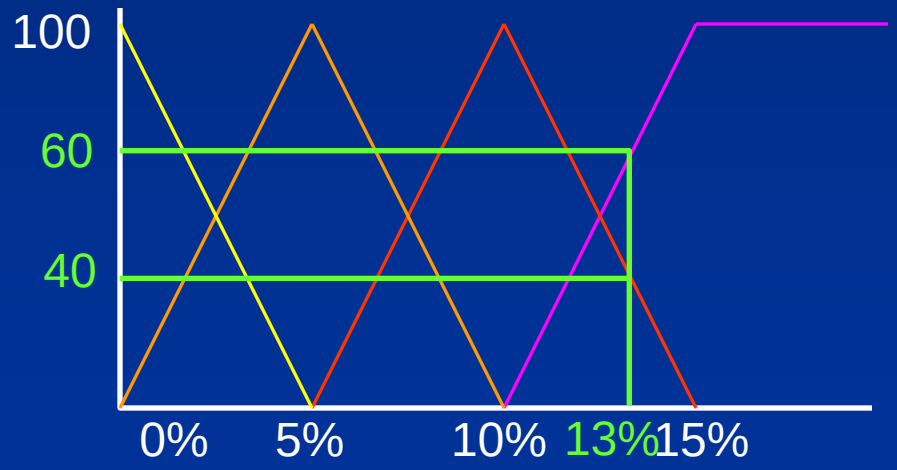
- Φ =Porosity (percentage)
  - Φ: ZERO if $0 \leq P < 5$
  - Φ: LOW if $5 \leq P < 10$
  - Φ: MEDIUM if $10 \leq P < 15$
  - Φ: HIGH if $15 \leq P$



Applying Best Known Values

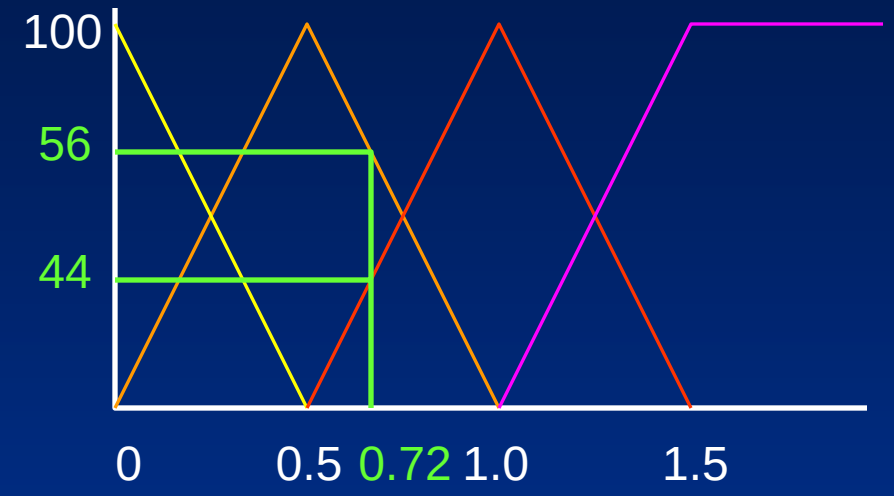
- As an example, 0.72 will be used as the best available value for TOC, and 13% will be used for the best available porosity.
- These two inputs will be used to develop a value for R, the prospect potential on a scale of 1 to 100.

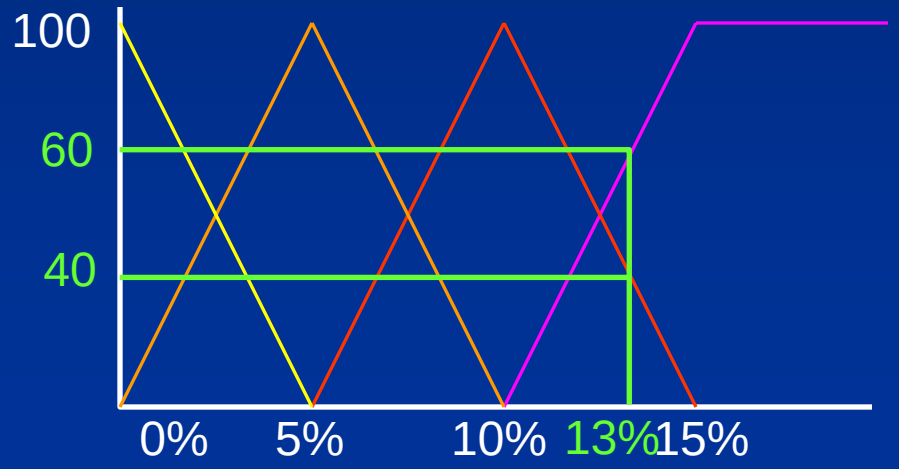




Membership

- Memberships of T
  - T(Zero)=0
  - T(Low)=56
  - T(Medium)=44
  - T(High)=0
- Memberships for Φ
  - Φ(Zero)=0
  - Φ(Low)=0
  - Φ(Medium)=40
  - Φ(High)=60





Rules – Expert Knowledge

1) If T is zero then R is zero
2) If Φ is zero then R is zero
3) If T is low and Φ is low or medium, then R is low
4) If T is low and Φ is high then R is medium
5) If T is medium and Φ is low then R is low
6) If T is medium and Φ is medium or high, then R is medium
7) If T is high and Φ is low or medium then R is medium
8) If T is high and Φ is high then R is high

Applicable Rules

- The next step in the process is to determine the strength of each of the fired rules using the set theory operators min for “and” and max for “or”.
- Beginning with rule 3, T has a low with membership value of 56, Φ low with membership value of 0 and Φ medium with membership value of 40. So, Φ is low ***or*** medium with a membership value of 40. Rule 3 is then “fired” with a strength of 40, using min (56,40) to arrive at this value.

Fired Rules

- rule 4 fired with a strength of 56 and
- rule 6 fired with a strength of 44.
- Rule 4 and 6, however, both result in R being medium, the two are combined using the max operator.
- In the final results, R is medium with strength of 56 and low with strength of 40.

Defuzzification

- To obtain a numerical value for R, on a scale of 1 to 100, the median values of 10 for low, 50 for medium and 90 for high are considered. Then using the strengths computed previously, R can be calculated as follows:
  - R = 0.40*(10)+0.56*(50) = 32
- A poor risk, assuming only these two factors apply:
  - Real problems involve hundreds of potential rules.

Application to Prospecting

- The project has developed extensive knowledge bases by interviewing Expert Delaware and Devonian Explorationist's.
- We have also developed Answerbases, for each play, so that the software models could be tested and global predictions made.
- The Answerbase is completely customizable by users and is available via the internet as a separate database.

Procedure

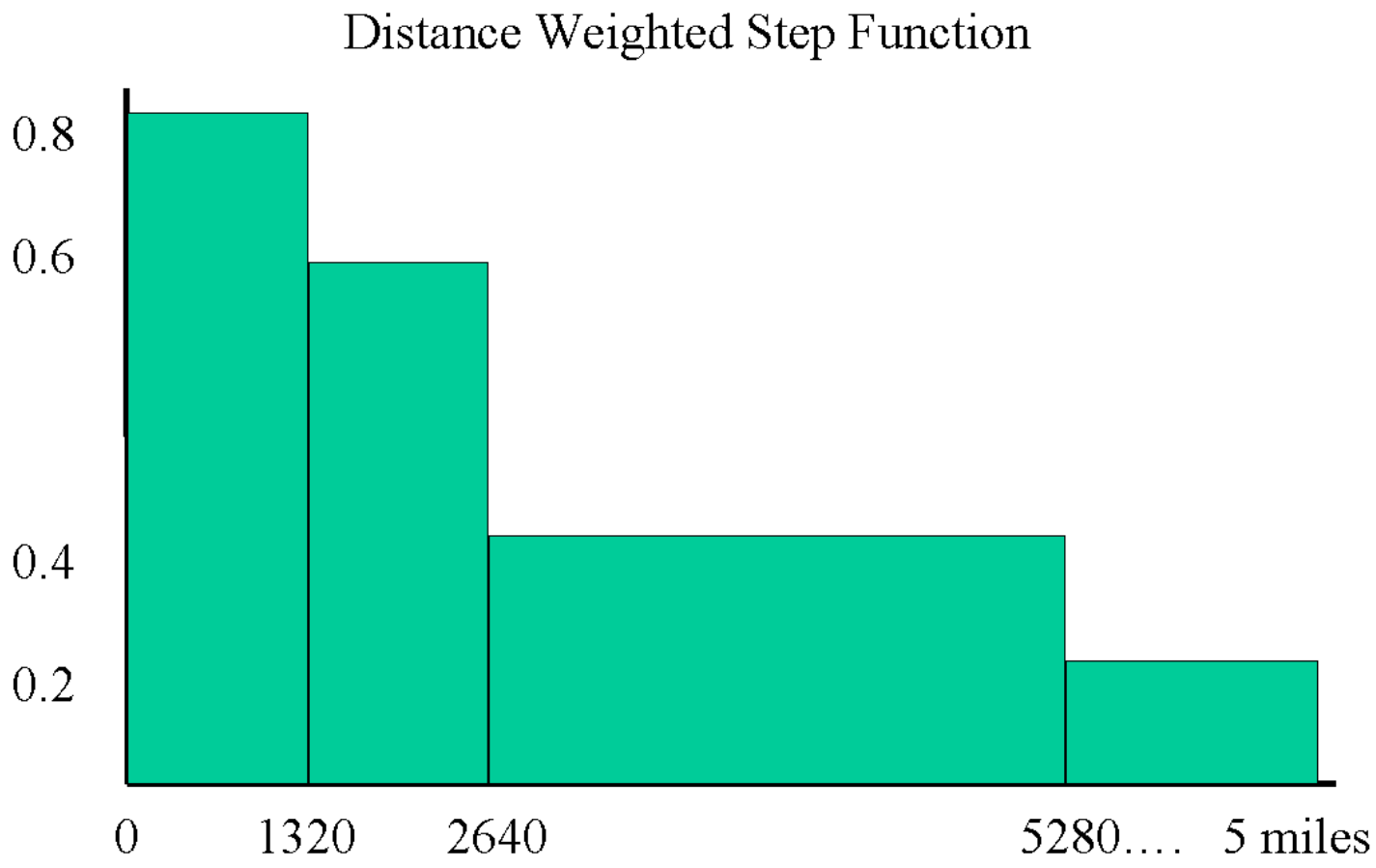
- Experts defined for us a number of important broad questions and dozens of associated rules.
- These Rules were written out in crisp form, and flags were assigned based on their relative value to the system:
  - Used to calculate the crisp models

Fuzzification of Brushy Canyon Rules

- The Rules, or stored knowledge are based on a composite expert opinion. They are often listed in semi-linguistic terms such as:
  - If distance to the nearest producing well is less than one 40 acre spacing (1320 ft) then the initial prospect quality is Very Good.
- Or
  - If the distance to the nearest producing well is less than two spacings (2640 ft) then the initial prospect quality is Good.

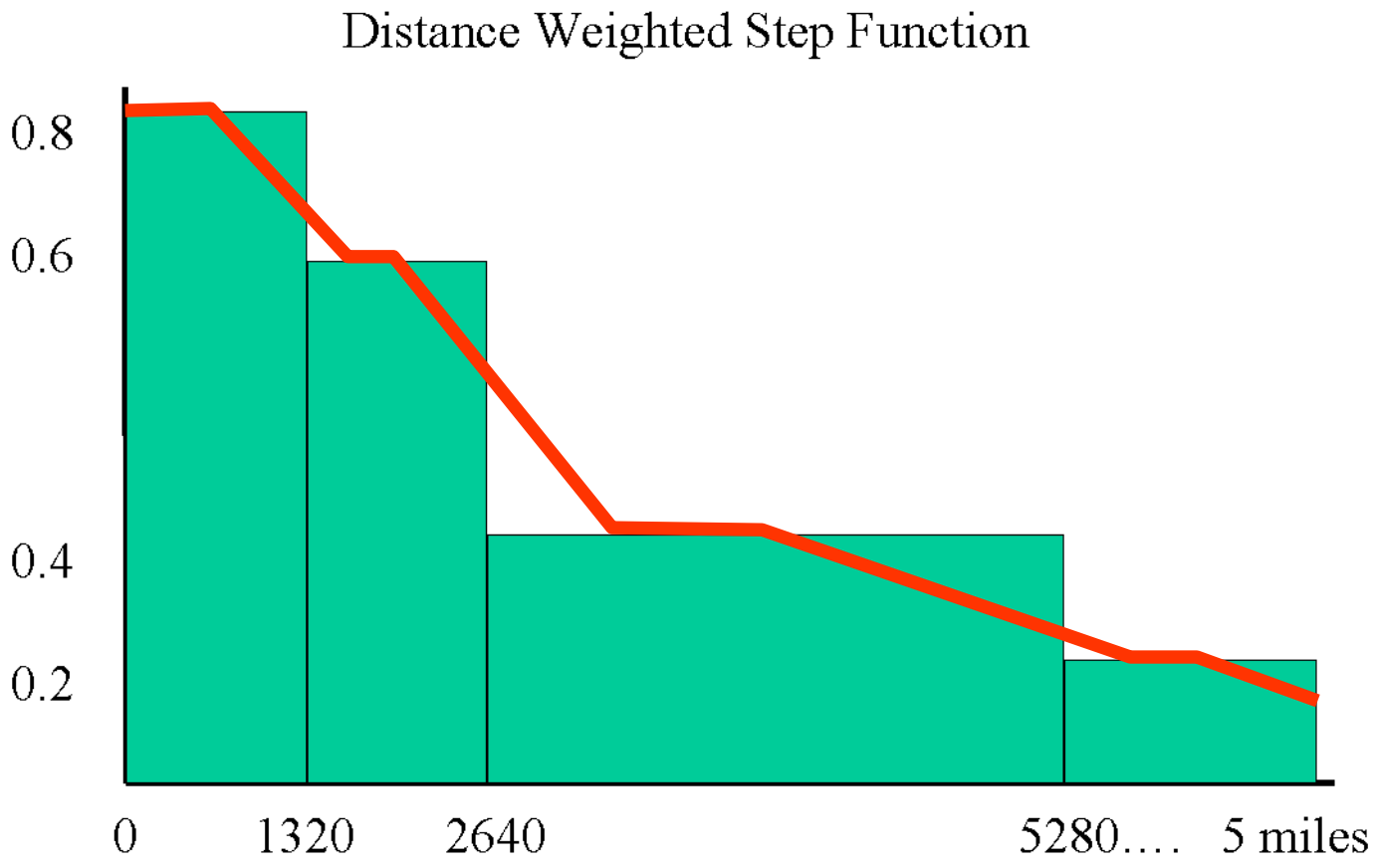
Fuzzification of Rules

- These can be formalized by writing logical if - then statements, but these will fail to capture the inherent fuzziness of the data:
  - If dist < 1320 then Quality = 0.8
  - If 1320 < dist < 2640 then Quality = 0.6
  - If 2640 < dist < 5280 then Quality = 0.4
  - If 5280 < dist < 26400 then Quality = 0.2
  - Else Quality =0.05
- This data is shown graphically on the next slide.


Distance Weighted Step Function
0.8
0.6
0.4
0.2
0
1320
2640
5280….
5 miles

Fuzzified Rules

- Each set of rules is defined with fuzzy membership functions instead of by crisp values.
- This allows the system to show the similarity of points that are 1319 ft and 1321 ft from the nearest prospect, whereas in the crisp model those values would be strongly different, though only 2 ft apart.


Distance Weighted Step Function
0.8
0.6
0.4
0.2
0
1320
2640
5280….
5 miles

Project Details

Rules

- Experts defined a number of important broad questions and dozens of associated rules.
- Also, heuristic rules were derived directly from the analysis of regional and local data.
- These Rules were written out in crisp form, and flags were assigned based on their relative value to the system.
- Fuzzy sets were defined to convert the crisp values to fuzzy values.

Delaware Trap Assessment Rule Categories

- Distance to nearest production or oil show.
- Dip difference between prospect and nearest producing well.
- Thickness of the porous sands at the prospect.
- Existence of updip sand pinchouts.
- Consistency of formation thickness.
- Structure.

Delaware Formation Assessment Rule Categories

- Total organic carbon at prospect location.
- Thermal maturity of source rocks.
- Distance to high quality downdip source rocks.

Delaware Regional Assessment Rule Categories

- Predicted production at the location.
- Distance to higher predicted production.
- Consistency of predicted production.
- Location of prospect in the producing basin
- Thickness of the porous sands.
- Structure.
- Gravity.

Devonian Trap Assessment Rule Categories

- Evaluate Seal/Cap.
- Closure on structure.
- Possibility of flexure fracturing.
- Potential for other porosity.
- Seismic verification of porosity.

Devonian Formation Assessment Rule Categories

- Total organic carbon of overlying Woodford Shale at prospect location.
- Primary Source rock thickness.
- Migration Potential.
  - Distance to rocks with high generative potential downdip.

Devonian Regional Assessment Rule Categories

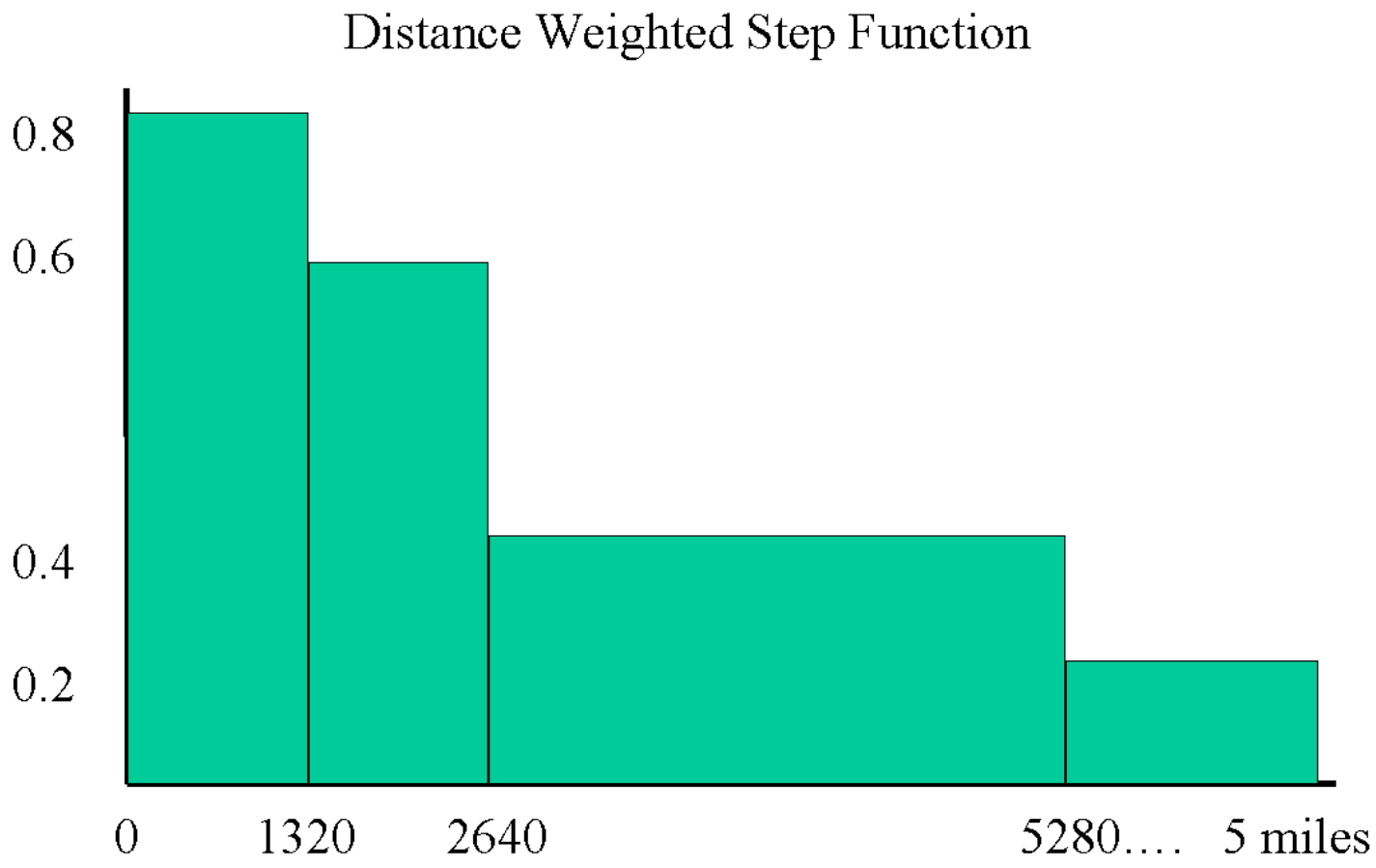
- Predicted production at the location.
- Other wells producing on structure.
- Location of prospect relative to other producing wells on structure.
- Gravity support of structure.
- Regional productive trends.

Devonian Structure Assessment Rule Categories

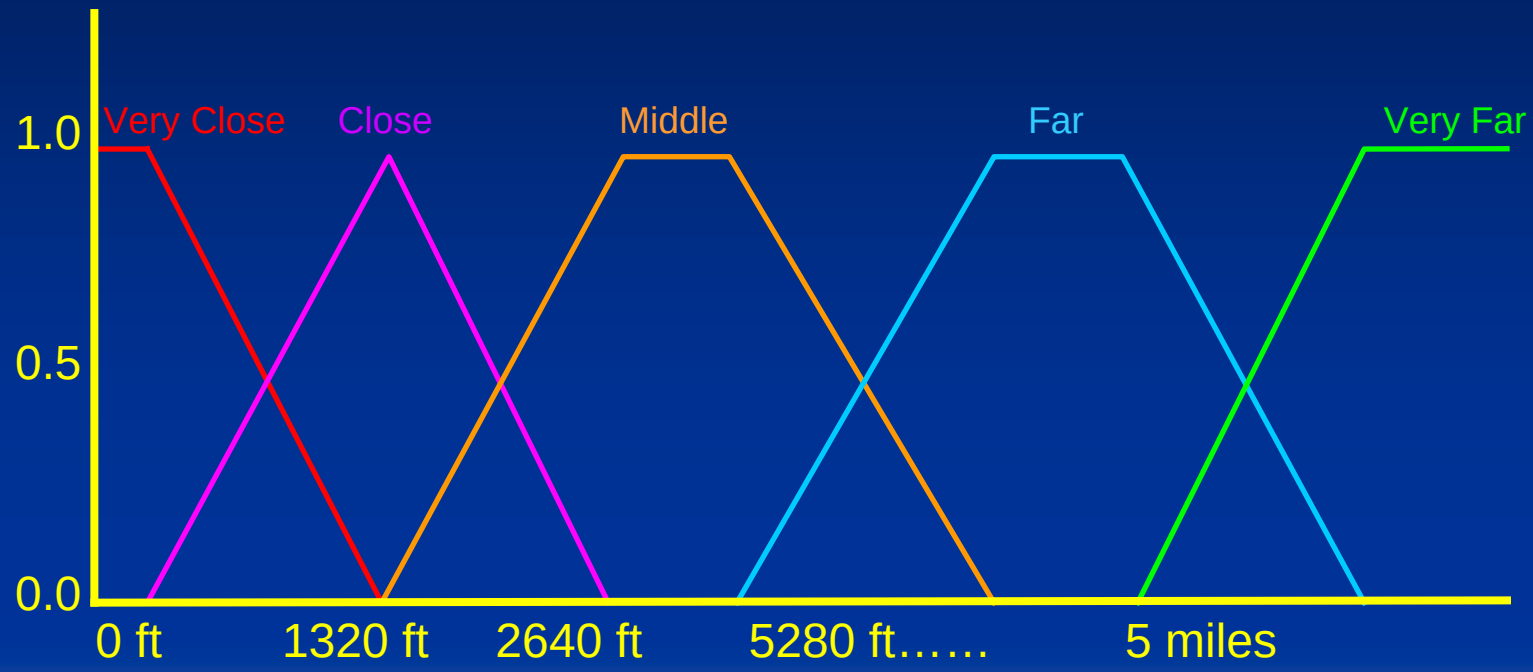
- Is there Paleo structure at the prospect?
- Structural relief.
- Fault bounding.
- Seismic verification of structure.

Fuzzy Reasoning Method

- *Trap*, *Formation*, *Structural* and *Regional* assessments start with an initial evaluation scaled between 0 and 1 using the answerbase or user input.
- As the expert system fires rules, a series of modifications to the initial value are applied.
- Each rule that is applied results in a modification flag.
- At the end of each section of questions the overall evaluation for that sub-system is calculated by applying the sum of the flags to the initial estimate.


Distance Weighted Step Function
0.8
0.6
0.4
0.2
0
1320
2640
5280….
5 miles

Distance Membership Functions



Initial Estimate Fuzzy Sets

Initial trap estimate computation

- Fuzzify d (distance to nearest producing well) using the membership function.
- Use the relevant rules (Trap Step 1) for inference and get the fuzzy set(s).
- Defuzzify the fuzzy set(s) and get the initial estimate using the following formula:

$$InitialValue = \frac{\sum c(x_i) * u_i(d)}{\sum u_i(d)}$$

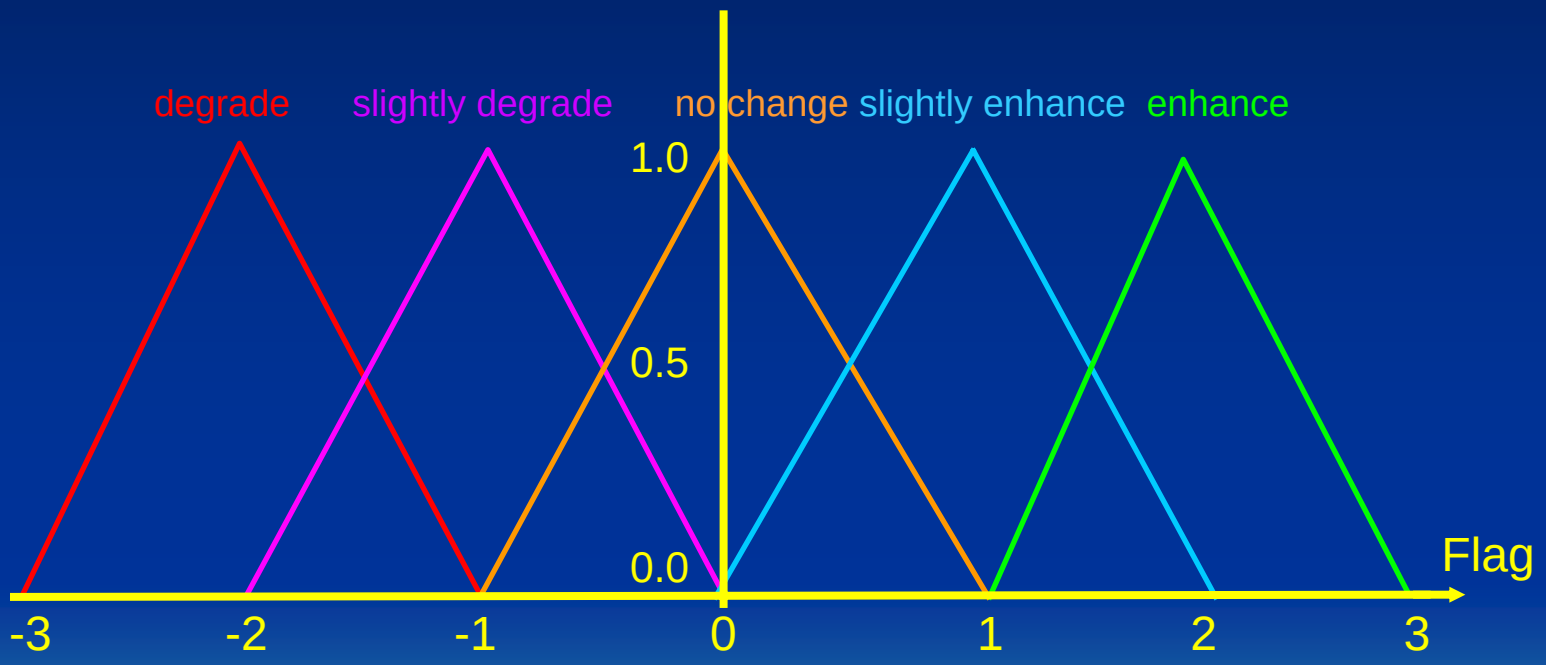
$c(x_i)$ The center value of the initial estimate fuzzy set for the i^{th} rule

$u_i(d)$ The degree of membership of d in the i^{th} fuzzy set

Modification flags

- The remaining rules of each section generate flags when fired.
- The generated flags are used to enhance or degrade the initial estimate and get the final estimate for each section.

Sample flag Membership function



Scoring of rules

- Method of Roots and Powers.
- Fractional Shifting method.
- Sum of Flags Method.

If N<0

$$trap\_estimate = (initial\_estimate)^{|n|+1}$$

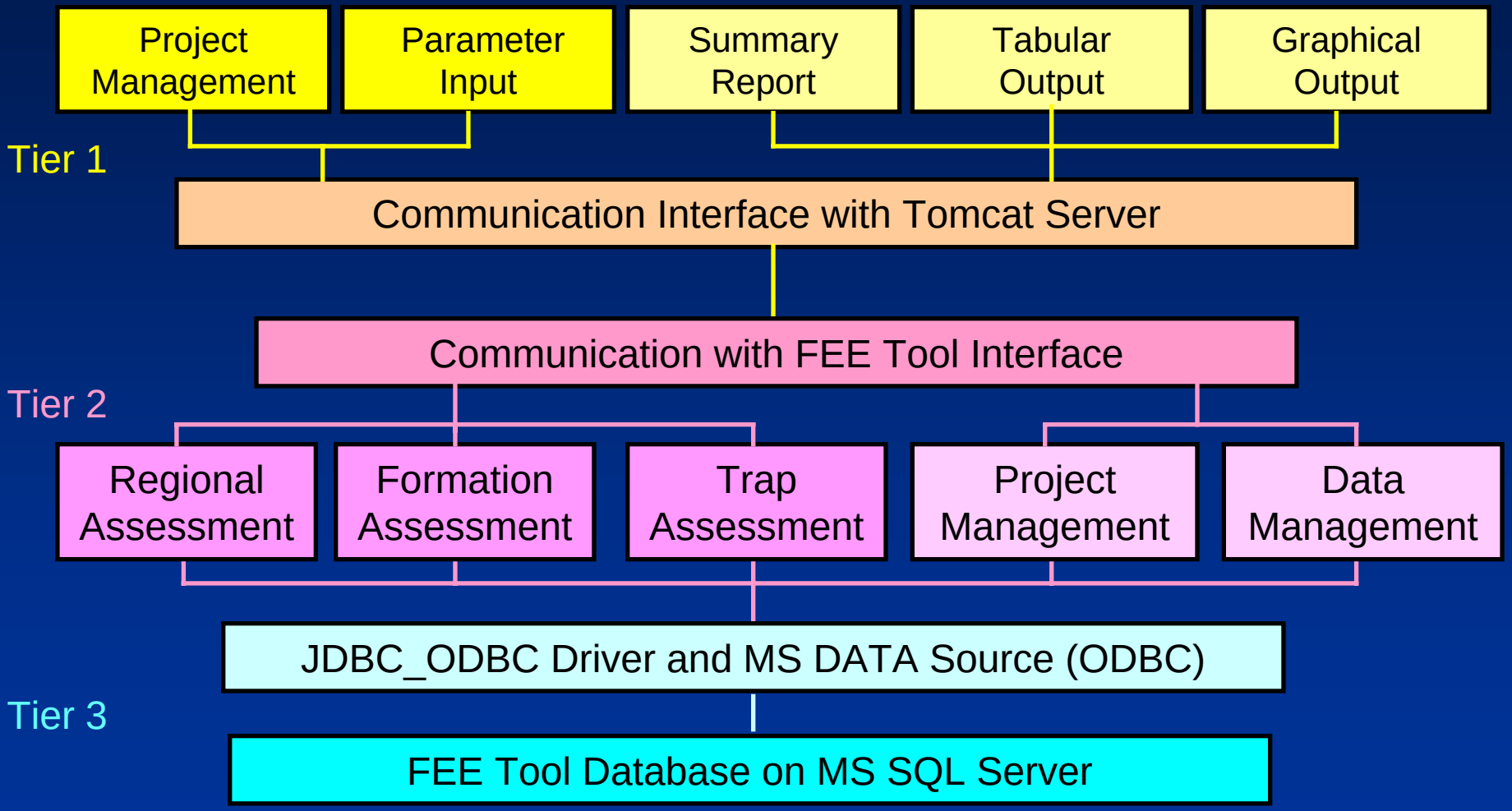
If N>0

$$trap\_estimate = (initial\_estimate)^{1/(n+1)}$$

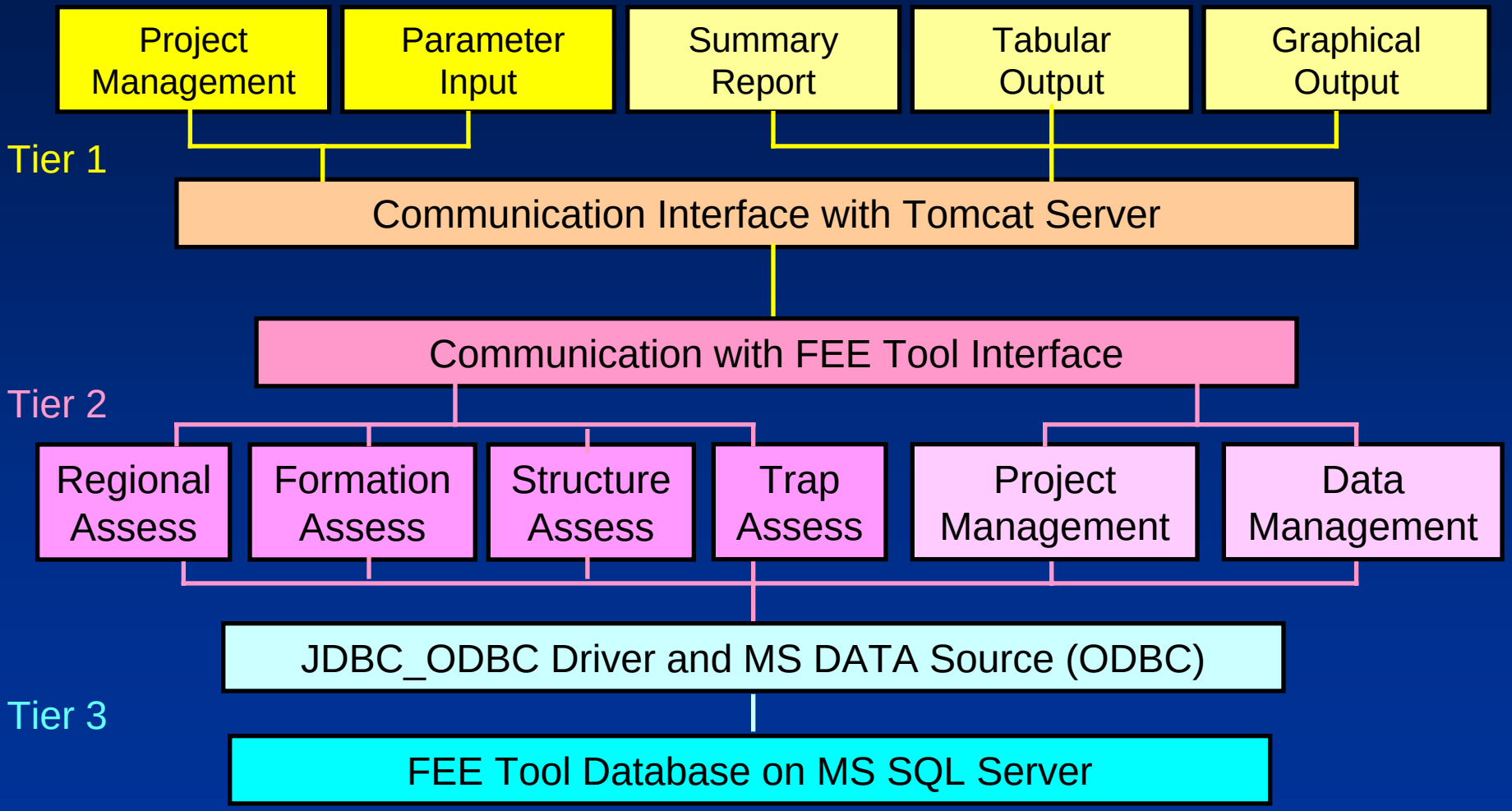
Overall Evaluation of a Prospect

- For the Delaware the weighing scheme was:
  - 50% trap, 25% formation and 25% regional.
- For the Devonian the weighing schemes was:
  - 45% Structure, 25% Formation, 15% Trap and 15% Regional.
- Used to combine the final estimate values (trap, formation, structural and regional) into one numerical value.
- Finally an associated linguistic output (poor, good, excellent, etc.) is calculated to help the user evaluate the numerical value.

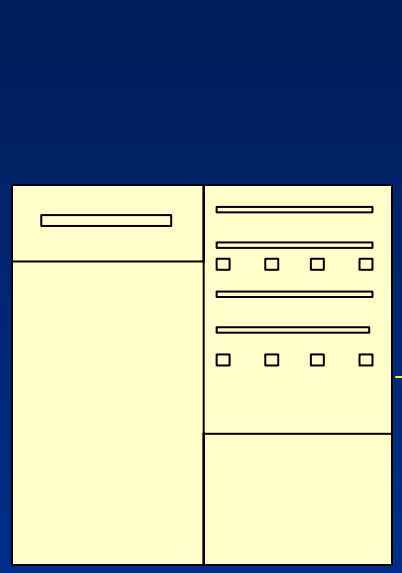
Delaware FEE Tool Architecture



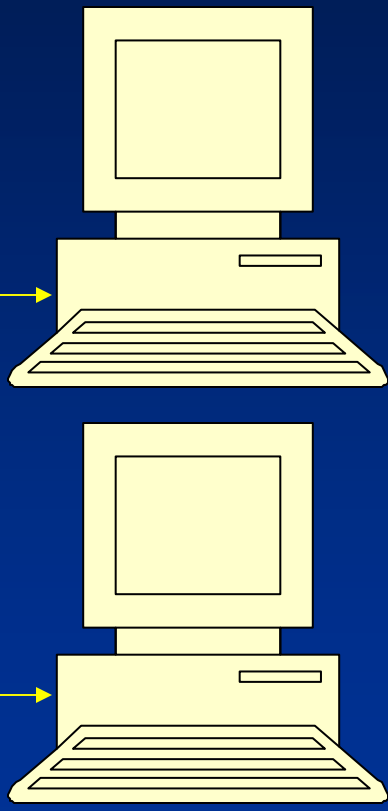
Devonian FEE Tool Architecture



The FEE Tool is a Web-based Application (Browser/Server)



(http://ford.nmt.edu)



WEB Server

Internet

Browser

REACT Server Configuration

Hardware platform -------Dell PowerEdge 4600 Server with 2x2.0GHZ--CPU , 2 GB memory and 480GB RAID HD.

Software platform:

- WEB Server --------IIS come with WIN2k
  - Supports html.
- Application Server-Tomcat 3.3
  - supports Java servlets.
- DB Server-----MS SQL Server 2000
  - Stores all data.
- FEE Tool ----- html/applet/jsp/servlet codes

User Side Configuration

- Hardware : Pc, Mac, Unix, etc.
- Software:
  - OS : Windows, MacOs, Linux, and Unix
  - Any browser that supports and has installed
  - JVM(Java Virtual Machine)
  - SSL (2.0/3.0) enabled.
  - Java plug-in

Development Environment

- Java SDK 1.4
- Tomcat 3.3
- MS SQL Server 2000
- DataBase Source (ODBC)

FEE Tool Security

- SSL(Secure Sockets Layer) is a technology which allows web browsers and web servers to communicate over a secured connection.
- Both servers AND browsers support SSL.
- The data being sent is encrypted by one side, transmitted, then decrypted by the other side before processing:
  - State of the industry 128 bit encryption is used.
  - This protects proprietary information.

Reliability

Dependent on:

1. Hardware : ford Server and network
2. Software : System Software and FEE Tool.

The FEE Tool is very stable at this point in its evolution. The server is brought down for maintenance, and periodic upgrades to the FEE Tool software requiring rare brief interruptions of service.

Programming Statistics

- The maximum expected productivity of a skilled Java programmer is 1,060 lines per month:
  - About 30% of productivity is directly related to actual coding time.
- This estimates includes:
  - Requirements analysis
  - Time needed to understand the problem
  - Time needed for testing
  - Time required to ensure final product stability

Programming Statistics

- Software generated by the project represents about 10 programmer years.
- Most software development occurred in the final three years of the project.
  - Full-time staff represents about half the programming effort
  - An average of 4-5 graduate students working half-time represents the other half.

Summary

- Java Conventions were observed so that the code is easy to read, understand and maintain.
- All computer science students that worked on the project, have obtained full-time jobs in software development after graduation.
- The 127,000 lines of software developed for the project represents nearly 2000 pages if printed.
  - Source code can be found online at http://ford.nmt.edu.

FEE Tool Demonstration

Delaware Basin

Fuzzy Expert Exploration Tool

Incomplete or sparse information on types of data such as geologic or formation characteristics introduces a high level of risk for oil exploration and development projects. "Expert" systems developed and used in several disciplines and industries have demonstrated beneficial results. A state-of-the-art exploration "expert" tool, relying on a computerized database and computer maps generated by neural networks, is being developed through the use of "fuzzy" logic, a relatively new mathematical treatment of imprecise or non-explicit parameters and values. Oil prospecting risk can be reduced with the use of a properly developed and validated "Fuzzy Expert Exploration (FEE) Tool."

The Fuzzy Expert Exploration Tool will eventually be generalized so that users in any part of the world will be able to add their own knowledge and data and make rapid evaluations of a large number of potential drilling sites in a systematic and consistent manner via the internet. A case study of the Lower Brushy Canyon formation of the Delaware basin, New Mexico is being used to verify the software and test the potential of the FEE Tool.

Below are links instructing potential users how to access and utilize the system for the Delaware Basin specific FEE Tool, to related regional data, and to collaterally developed on-line neural network software and input selection code utilizing fuzzy logic.

Delaware Basin FEE Tool

Download the User Manual .(about 3.8MB)

A password protected account is required to use the FEE tool while it is in beta testing.

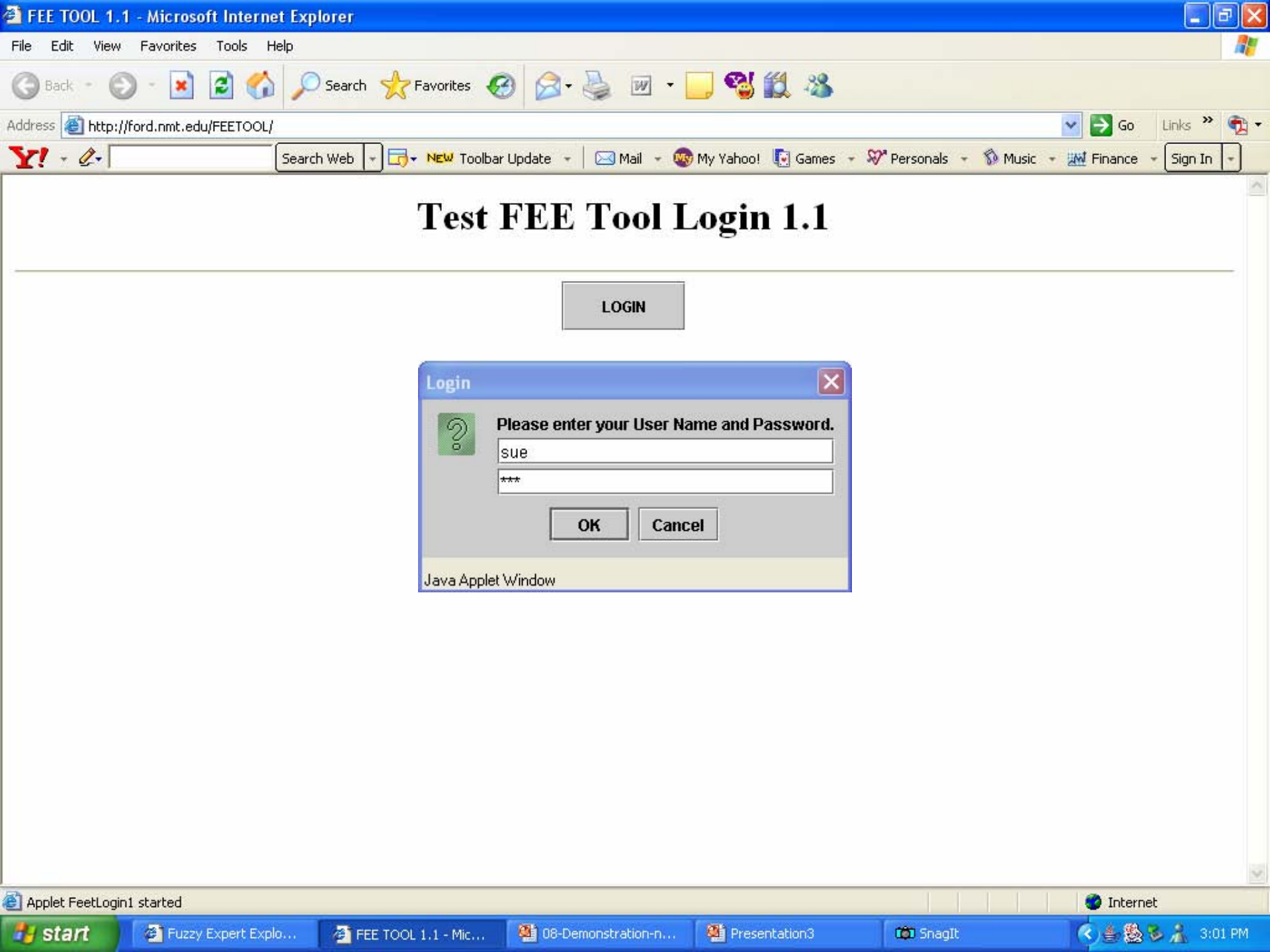
E-mail Principal Investigator Robert Balch, , call (505) 835-5305 for information, or register on line.

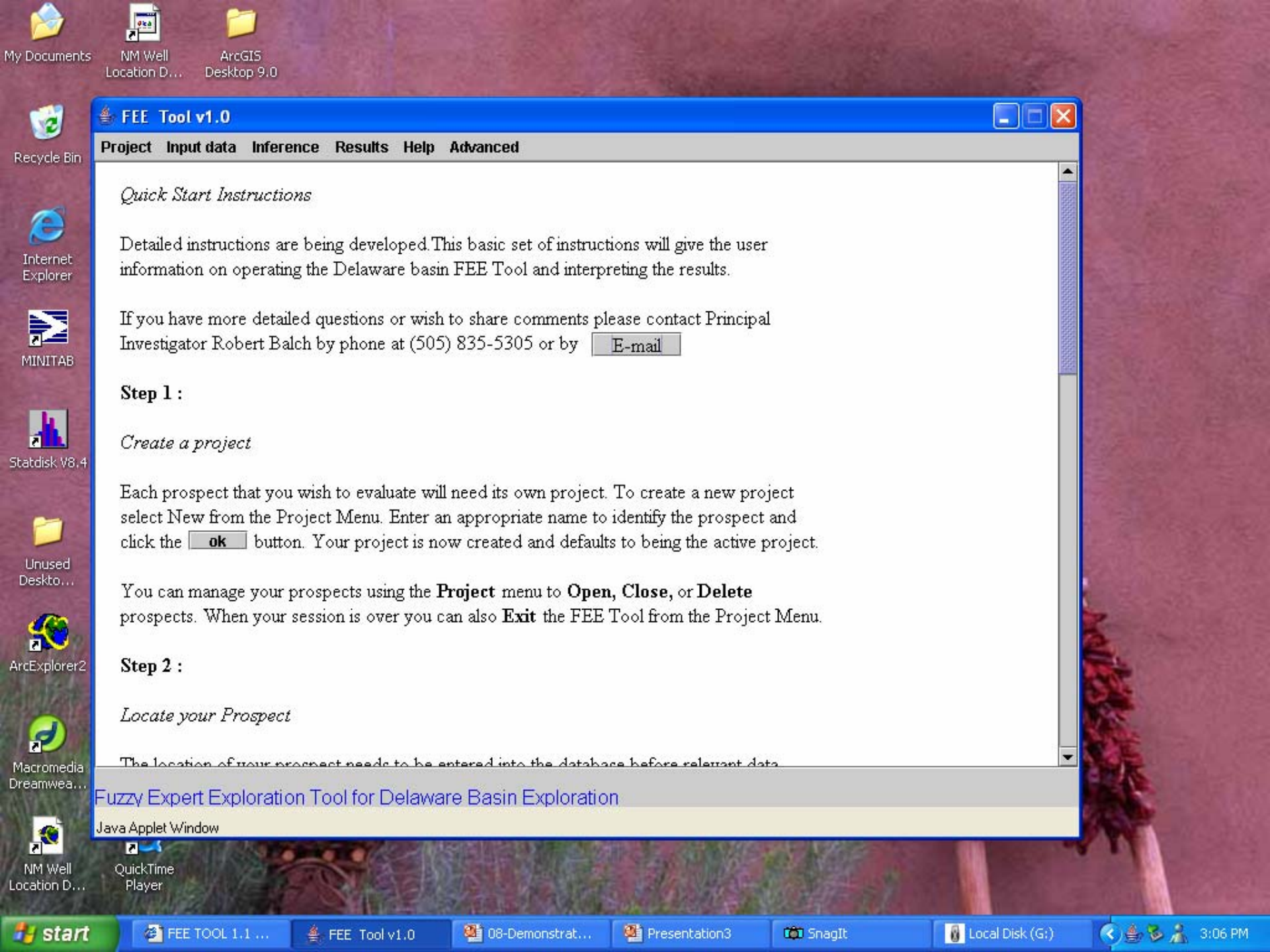
Download the off-line version (about 12.9 MB).(Need Java on your computer to run)

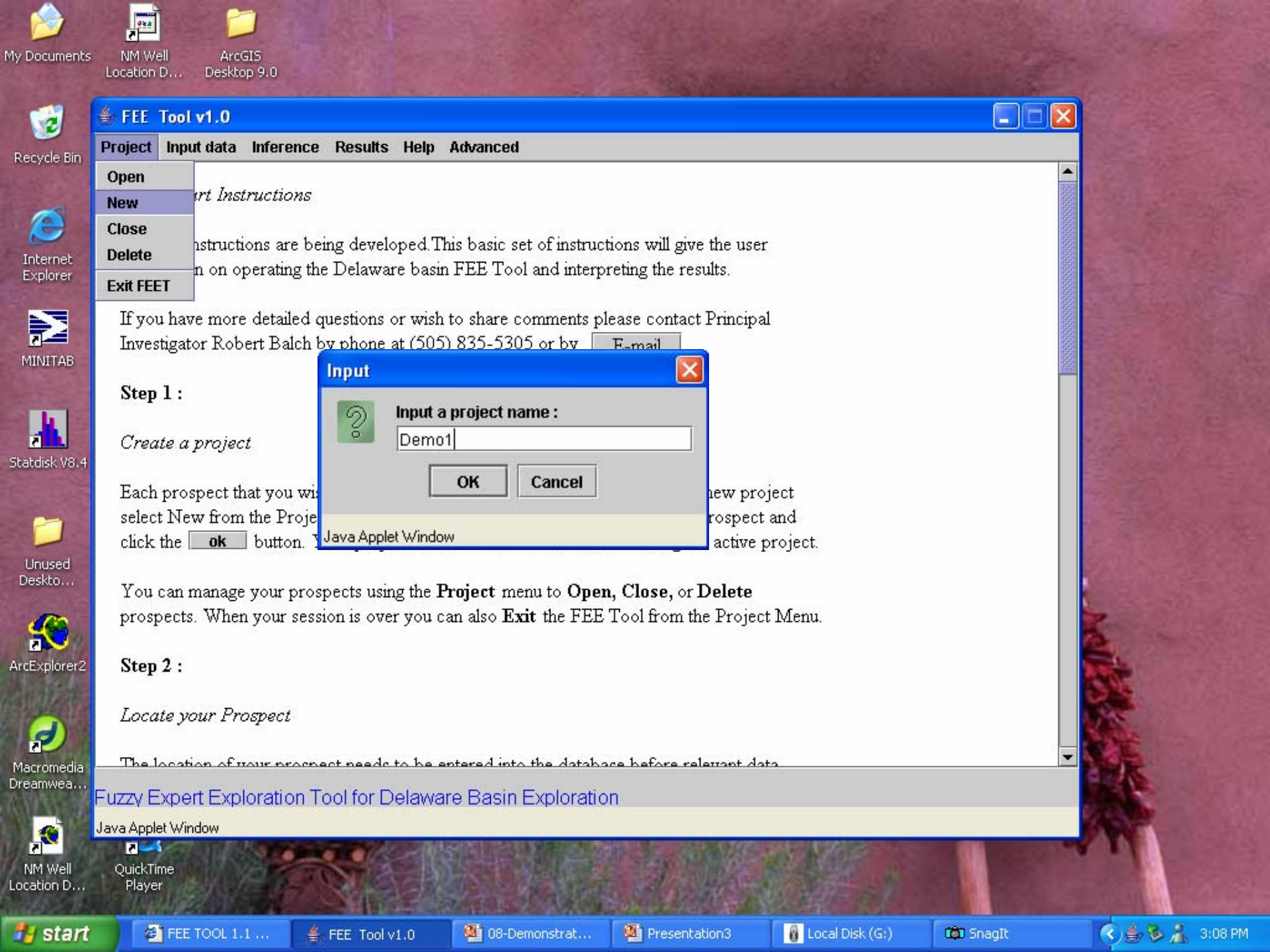
Devonian FEE Tool

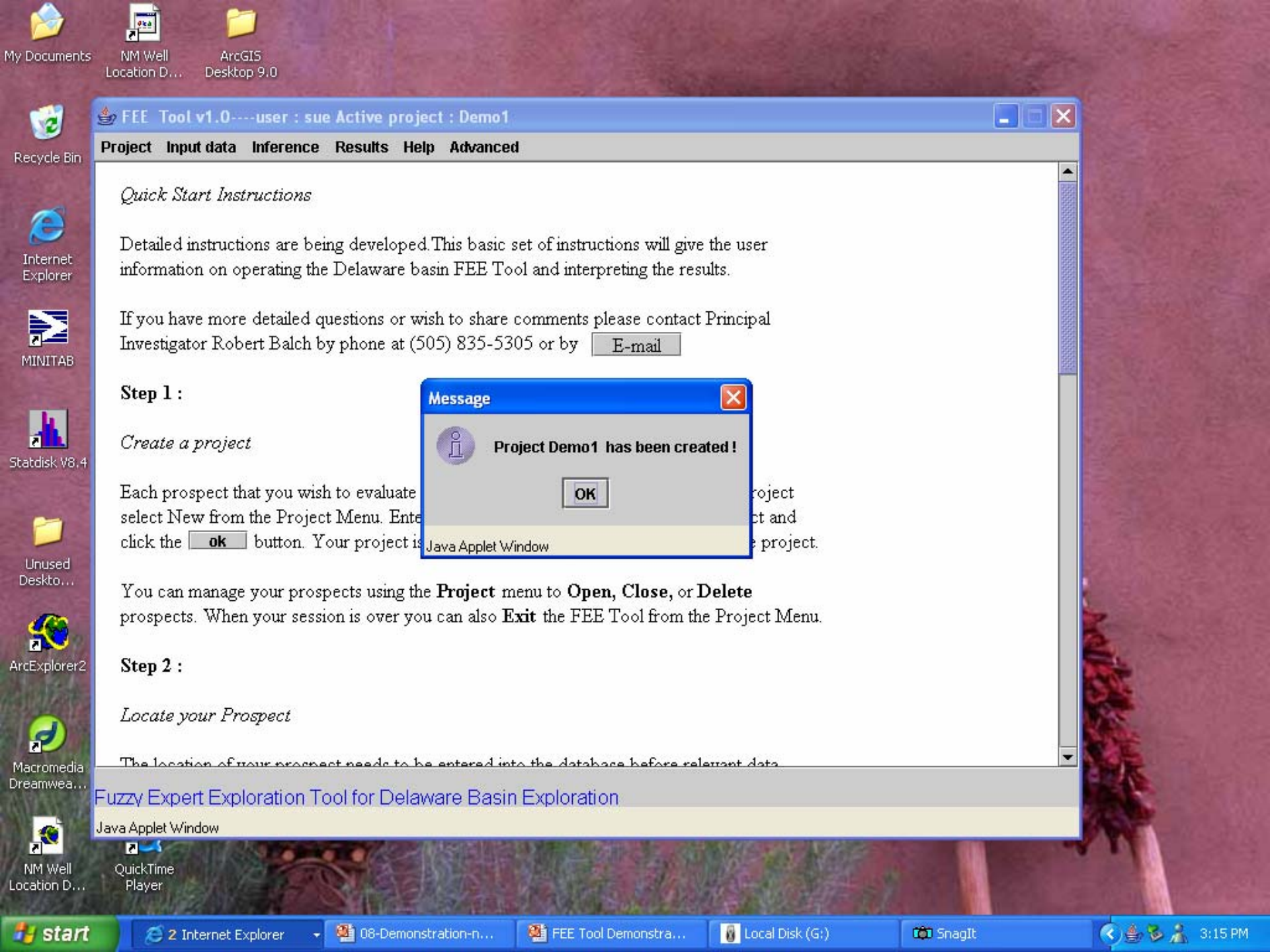
Download the User Manual .(about 3.8MB)

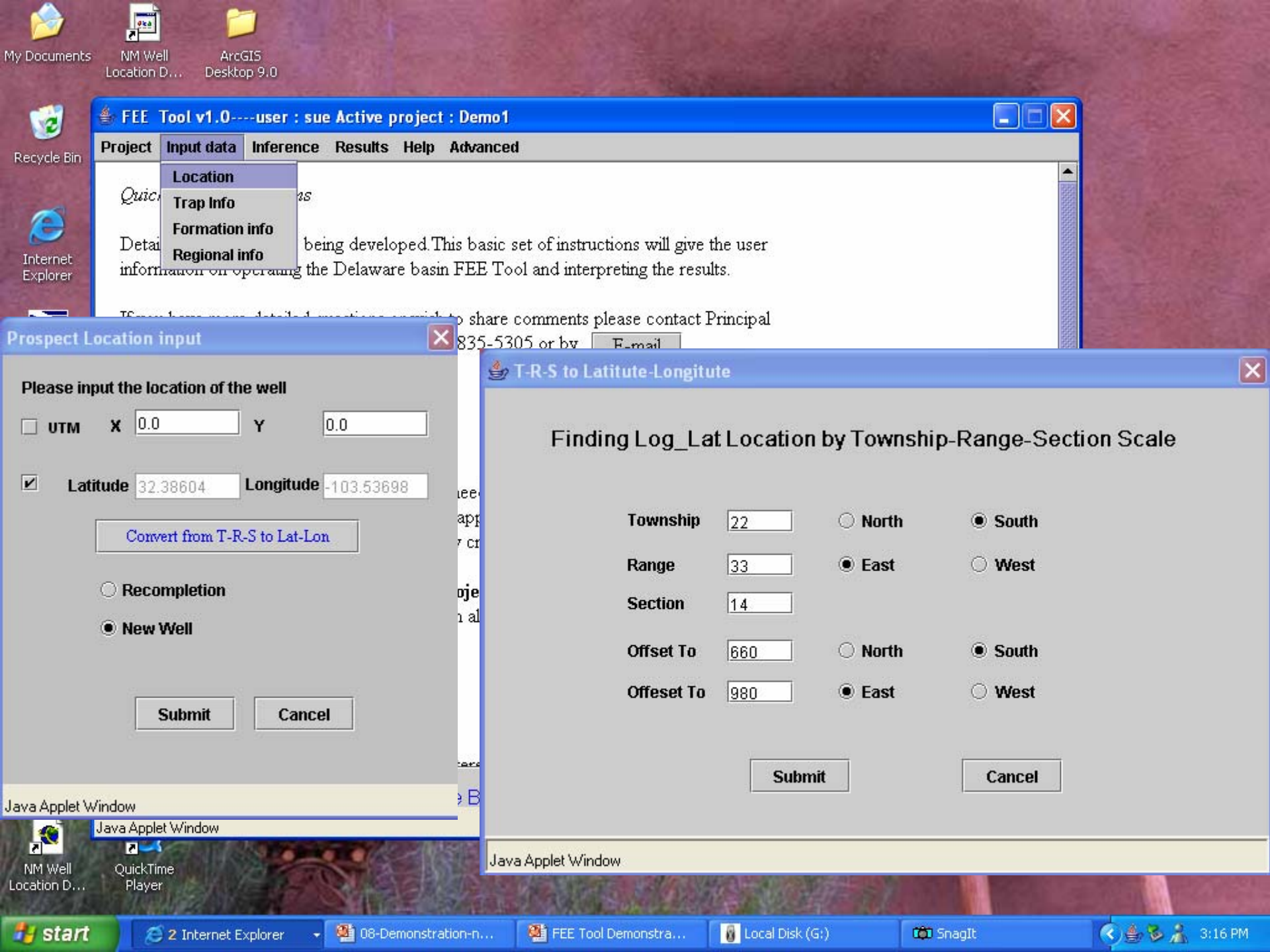
A password protected account is required to use the FEE tool while it is in beta testing.

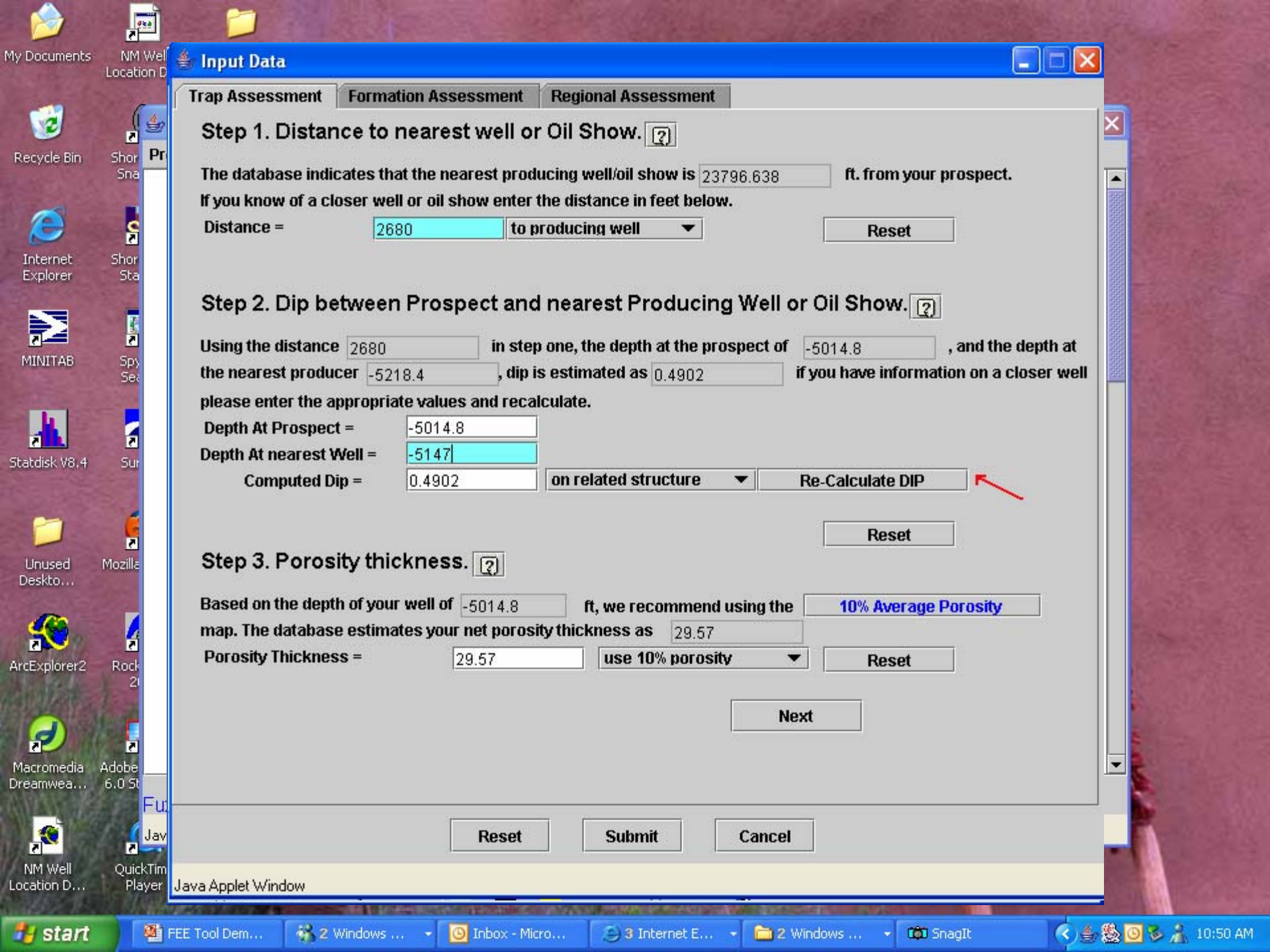

FEE TOOL 1.1 - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://ford.nmt.edu/FEETOOL/
Go Links
Search Web Toolbar Update Mail My Yahoo! Games Personals Music Finance Sign In
Test FEE Tool Login 1.1
LOGIN
Login
Please enter your User Name and Password.
sue
***
OK
Cancel
Java Applet Window
Applet FeetLogin1 started
Internet
start
Fuzzy Expert Explo...
FEE TOOL 1.1 - Mic...
08-Demonstration-n...
Presentation3
SnagIt
3:01 PM

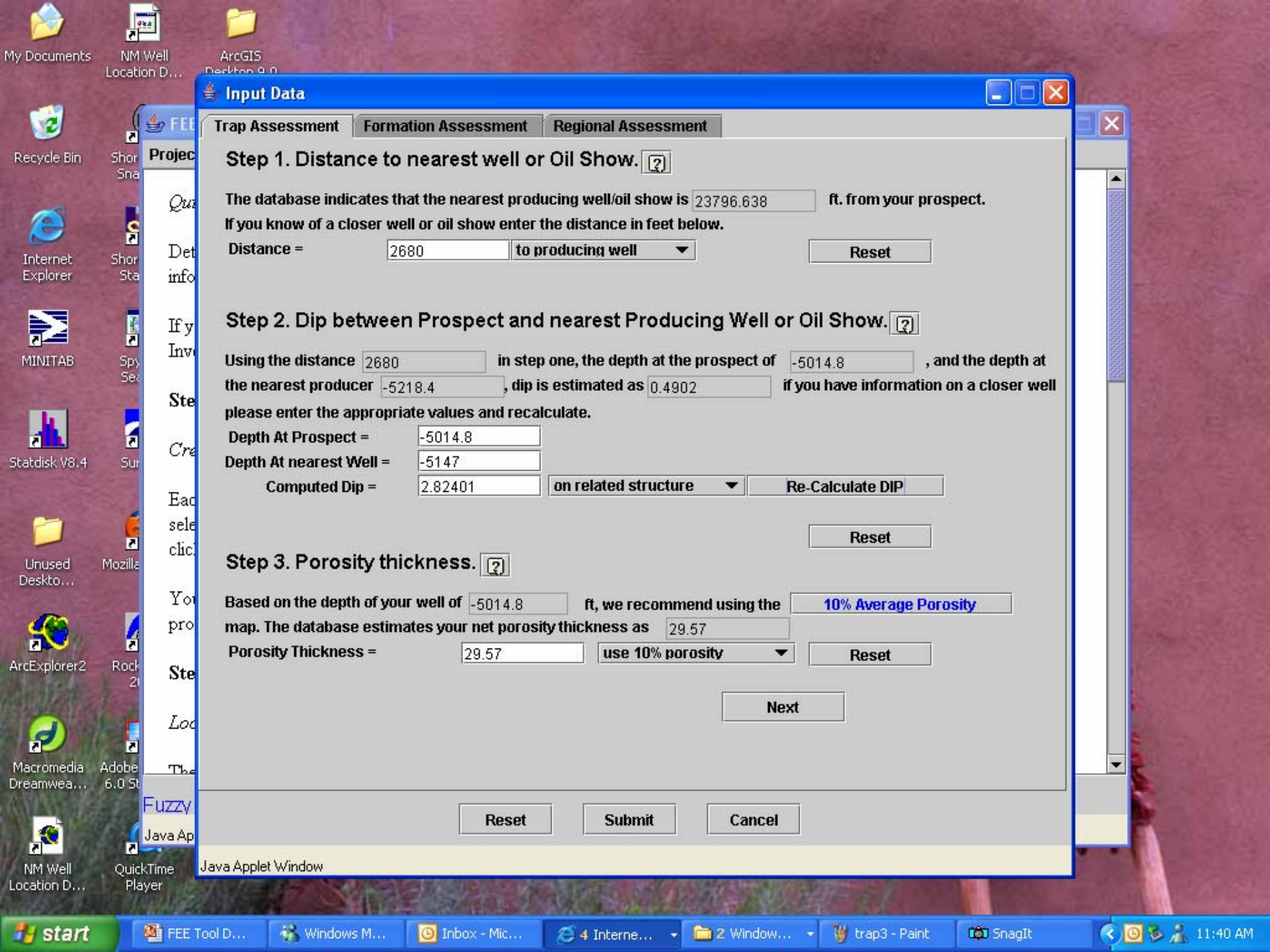

My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0
Project Input data Inference Results Help Advanced
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user information on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project select New from the Project Menu. Enter an appropriate name to identify the prospect and click the ok button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
start
FEE TOOL 1.1 ...
FEE Tool v1.0
08-Demonstrat...
Presentation3
SnagIt
Local Disk (G:)
3:06 PM

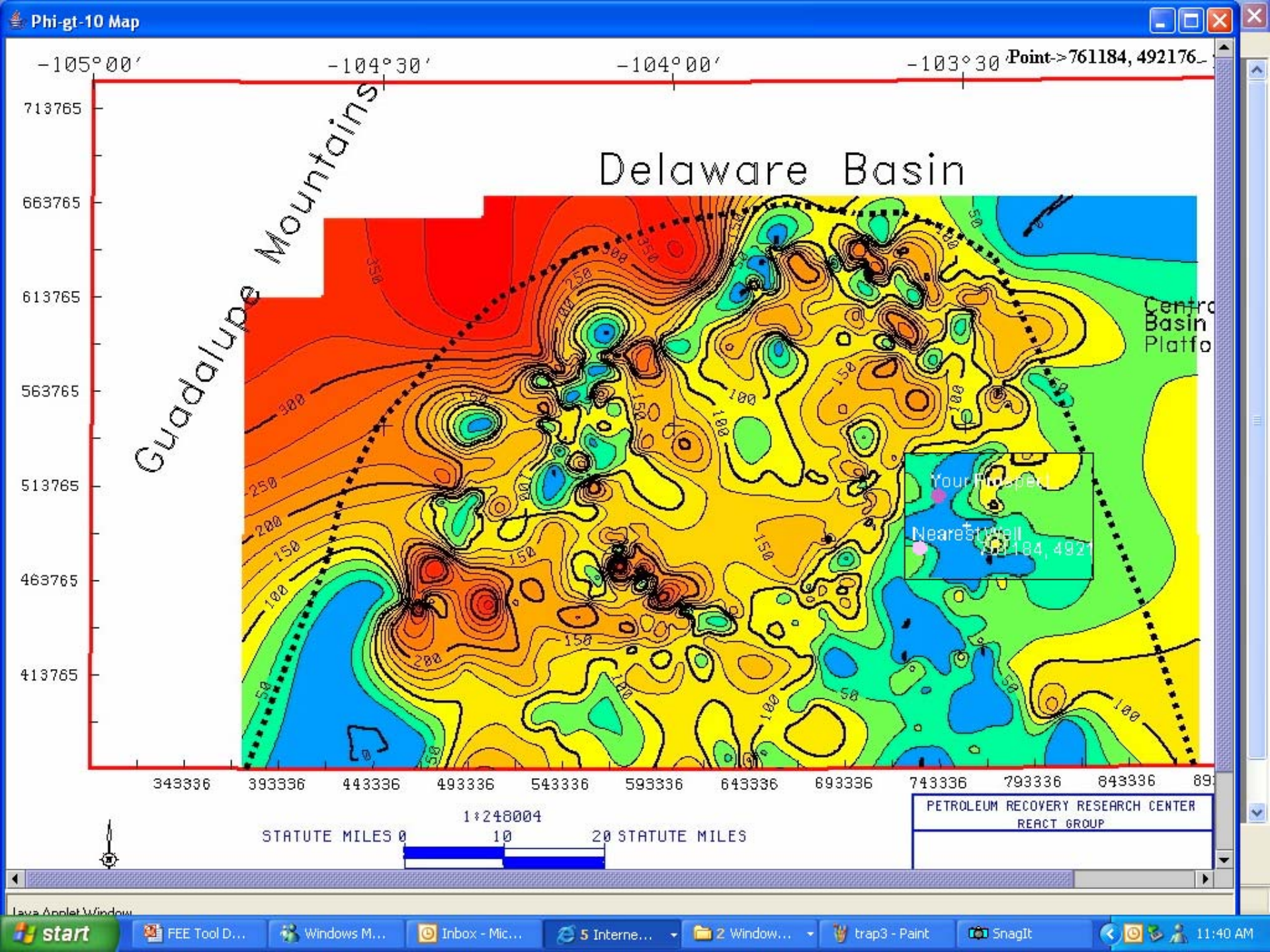

My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0
Project
Input data
Inference
Results
Help
Advanced
Open
New
Close
Delete
Exit FEET
rt Instructions
nstructions are being developed.This basic set of instructions will give the user
n on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail
Step 1 :
Create a project
Each prospect that you wi
new project
select New from the Proje
rospect and
click the ok button.
active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Input
Input a project name :
Demo1
OK
Cancel
Java Applet Window
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
start
FEE TOOL 1.1 ...
FEE Tool v1.0
08-Demonstrat...
Presentation3
Local Disk (G:)
SnagIt
3:08 PM

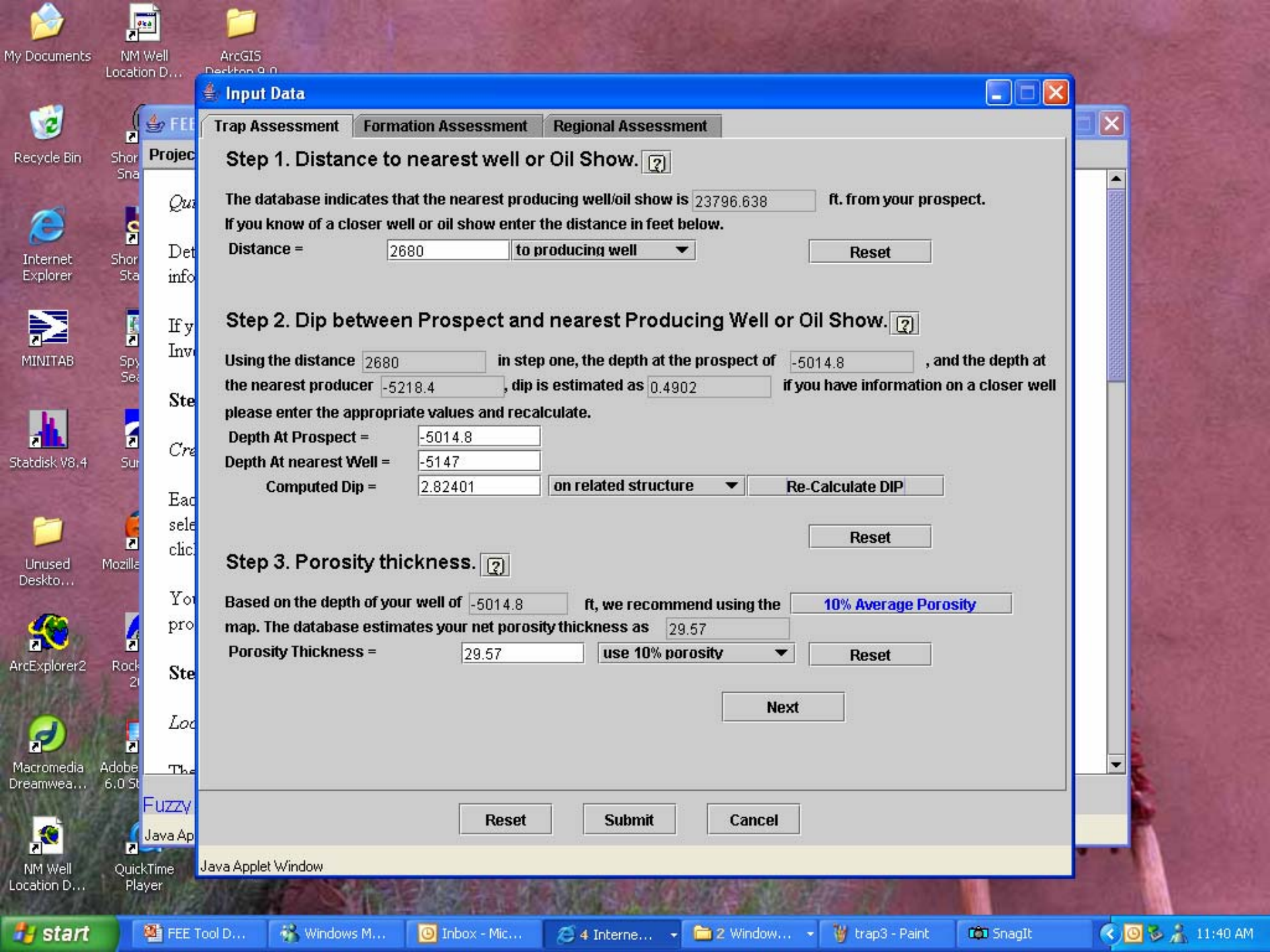

My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0----user : sue Active project : Demo1
Project Input data Inference Results Help Advanced
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user information on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate
select New from the Project Menu. Ente
click the ok button. Your project is
project.
Message
Project Demo1 has been created !
OK
Java Applet Window
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
start
2 Internet Explorer
08-Demonstration-n...
FEE Tool Demonstra...
Local Disk (G:)
SnagIt
3:15 PM

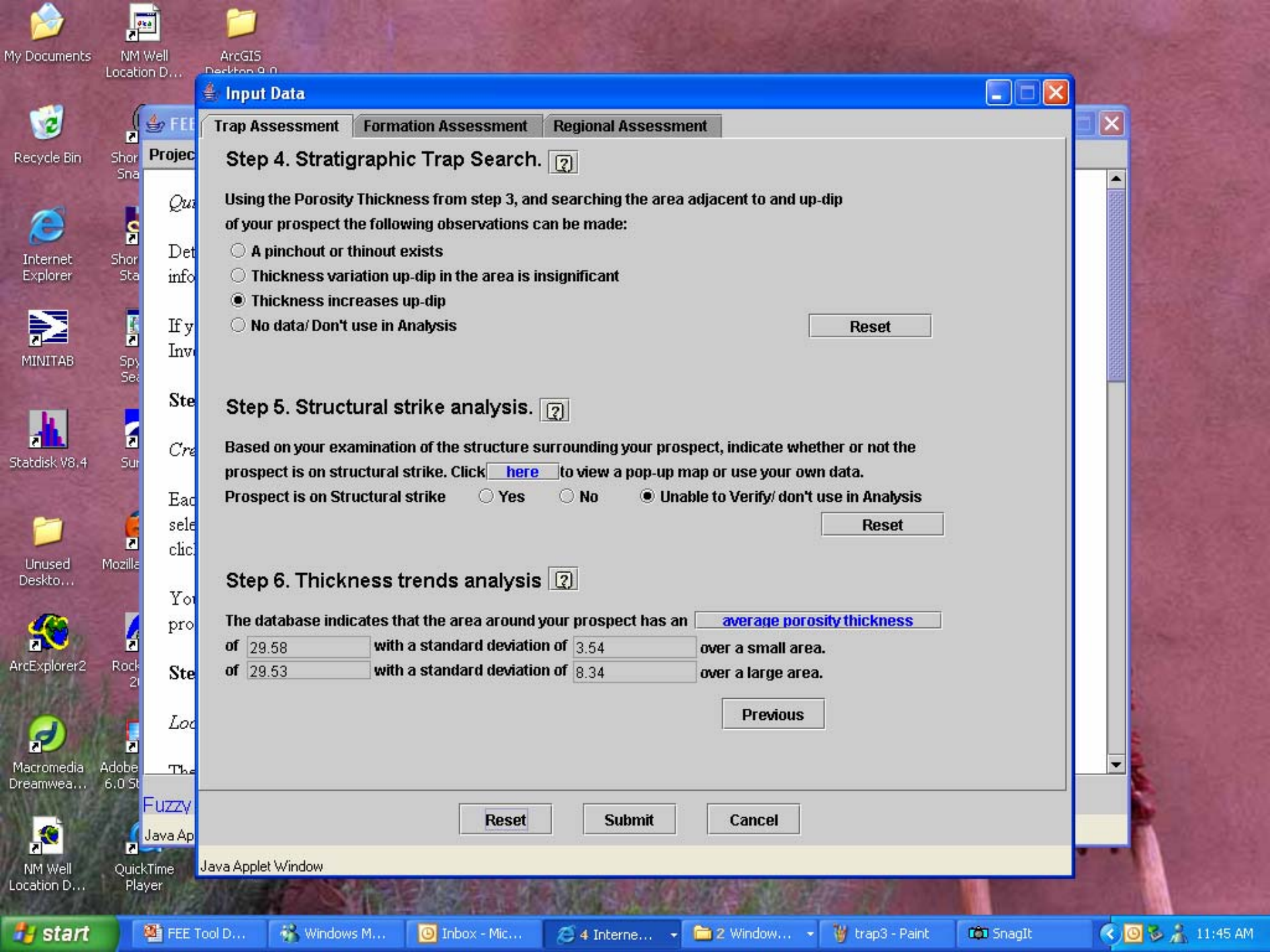

My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
FEE Tool v1.0----user : sue Active project : Demo1
Project
Input data
Inference
Results
Help
Advanced
Location
Trap Info
Formation info
Regional info
being developed.This basic set of instructions will give the user
the Delaware basin FEE Tool and interpreting the results.
share comments please contact Principal
E-mail
Prospect Location input
Please input the location of the well
UTM
X
0.0
Y
0.0
Latitude
32.38604
Longitude
-103.53698
Convert from T-R-S to Lat-Lon
Recompletion
New Well
Submit
Cancel
Java Applet Window
Java Applet Window
T-R-S to Latitute-Longitute
Finding Log_Lat Location by Township-Range-Section Scale
Township
22
North
South
Range
33
East
West
Section
14
Offset To
660
North
South
Offeset To
980
East
West
Submit
Cancel
Java Applet Window
NM Well Location D...
QuickTime Player
start
2 Internet Explorer
08-Demonstration-n...
FEE Tool Demonstra...
Local Disk (G:)
SnagIt
3:16 PM

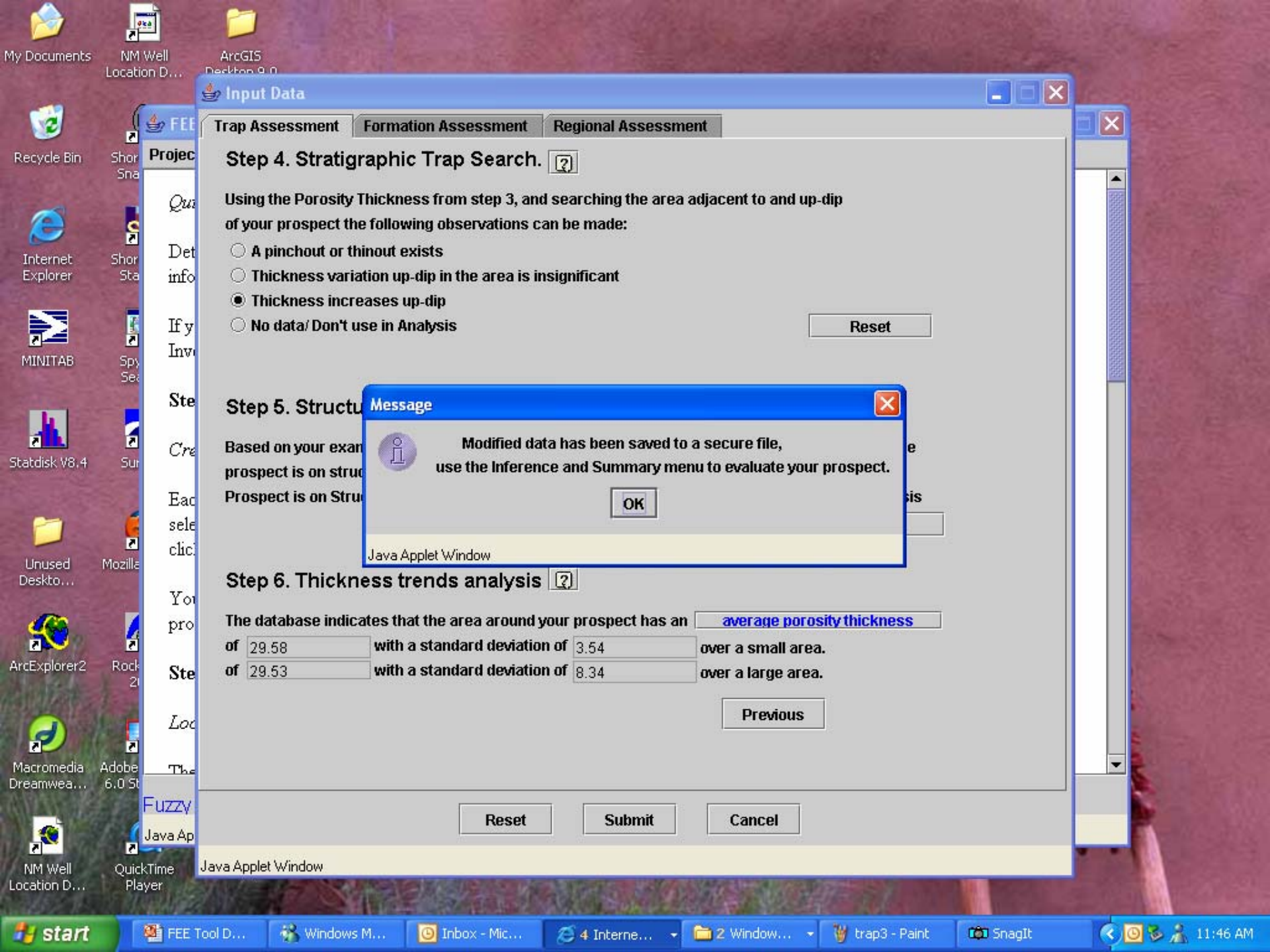

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 1. Distance to nearest well or Oil Show.
The database indicates that the nearest producing well/oil show is 23796.638 ft. from your prospect.
If you know of a closer well or oil show enter the distance in feet below.
Distance = 2680 to producing well
Reset
Step 2. Dip between Prospect and nearest Producing Well or Oil Show.
Using the distance 2680 in step one, the depth at the prospect of -5014.8 , and the depth at
the nearest producer -5218.4 , dip is estimated as 0.4902 if you have information on a closer well
please enter the appropriate values and recalculate.
Depth At Prospect = -5014.8
Depth At nearest Well = -5147
Computed Dip = 0.4902
on related structure
Re-Calculate DIP
Reset
Step 3. Porosity thickness.
Based on the depth of your well of -5014.8 ft, we recommend using the 10% Average Porosity
map. The database estimates your net porosity thickness as 29.57
Porosity Thickness = 29.57
use 10% porosity
Reset
Next
Reset
Submit
Cancel
Java Applet Window

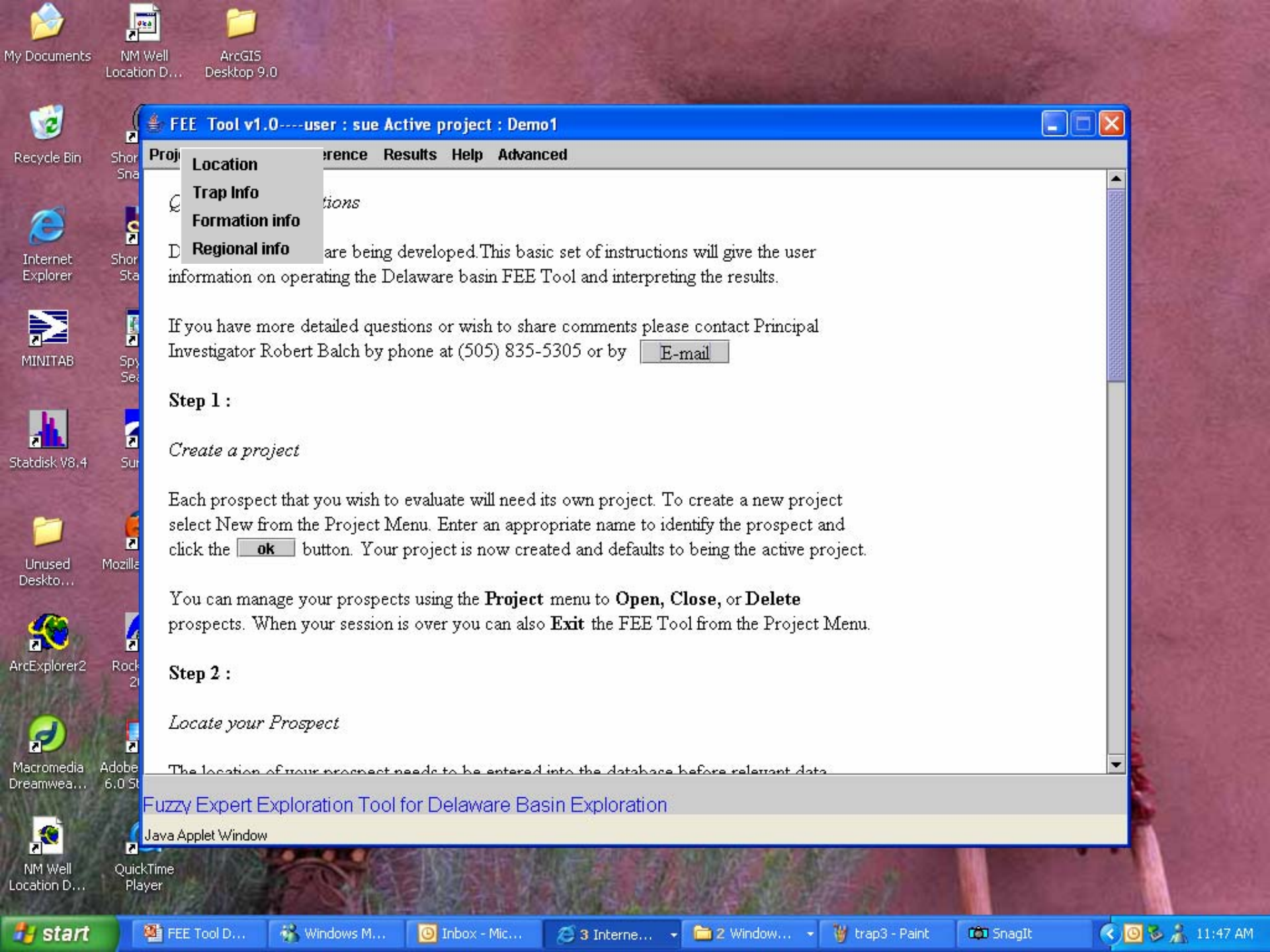

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 1. Distance to nearest well or Oil Show.
The database indicates that the nearest producing well/oil show is 23796.638 ft. from your prospect.
If you know of a closer well or oil show enter the distance in feet below.
Distance = 2680 to producing well
Reset
Step 2. Dip between Prospect and nearest Producing Well or Oil Show.
Using the distance 2680 in step one, the depth at the prospect of -5014.8 , and the depth at the nearest producer -5218.4 , dip is estimated as 0.4902 if you have information on a closer well please enter the appropriate values and recalculate.
Depth At Prospect = -5014.8
Depth At nearest Well = -5147
Computed Dip = 2.82401 on related structure
Re-Calculate DIP
Reset
Step 3. Porosity thickness.
Based on the depth of your well of -5014.8 ft, we recommend using the 10% Average Porosity map. The database estimates your net porosity thickness as 29.57
Porosity Thickness = 29.57 use 10% porosity
Reset
Next
Reset
Submit
Cancel
Java Applet Window

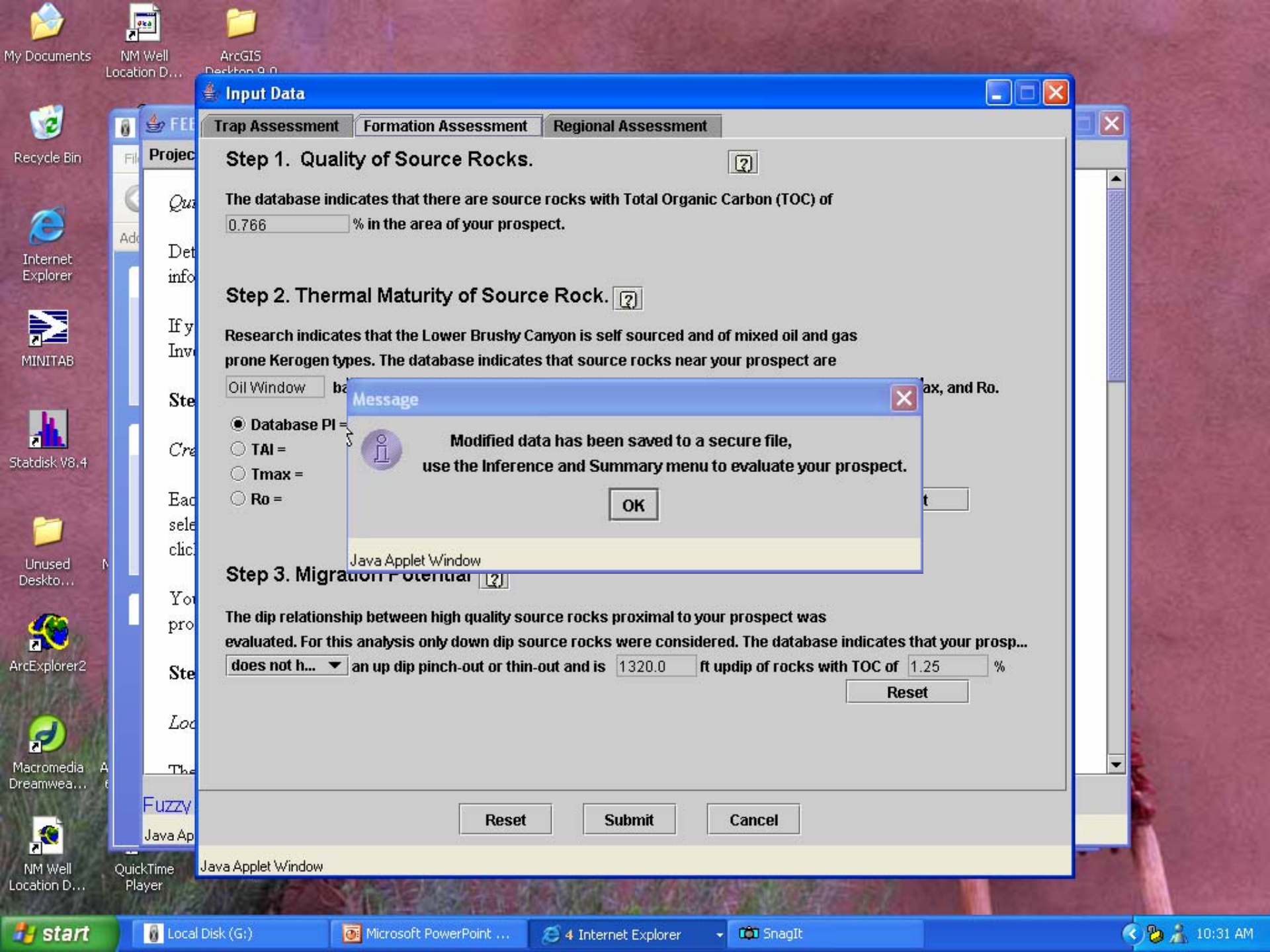

Phi-gt-10 Map
-105°00′
-104°30′
-104°00′
-103°30′
Point->761184, 492176
713765
663765
613765
563765
513765
463765
413765
Delaware Basin
Guadalupe Mountains
Central Basin Platfo
Your Prospect
Nearest Well
761184, 4921
343336
393336
443336
493336
543336
593336
643336
693336
743336
793336
843336
1:248004
STATUTE MILES 0
10
20 STATUTE MILES
PETROLEUM RECOVERY RESEARCH CENTER
REACT GROUP
start
FEE Tool D...
Windows M...
Inbox - Mic...
5 Interne...
2 Window...
trap3 - Paint
SnagIt
11:40 AM

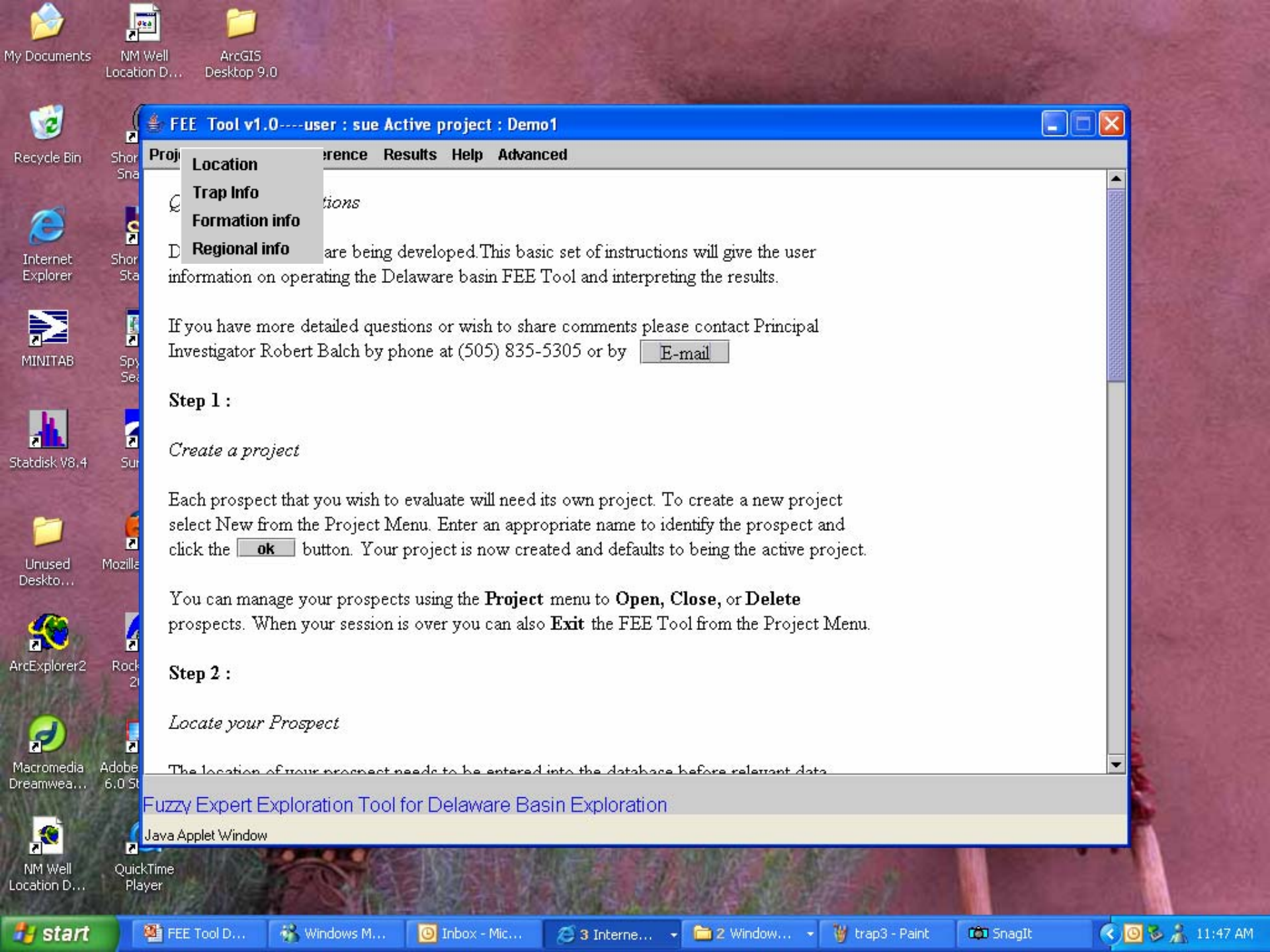

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 1. Distance to nearest well or Oil Show.
The database indicates that the nearest producing well/oil show is 23796.638 ft. from your prospect.
If you know of a closer well or oil show enter the distance in feet below.
Distance = 2680 to producing well
Reset
Step 2. Dip between Prospect and nearest Producing Well or Oil Show.
Using the distance 2680 in step one, the depth at the prospect of -5014.8 , and the depth at the nearest producer -5218.4 , dip is estimated as 0.4902 if you have information on a closer well please enter the appropriate values and recalculate.
Depth At Prospect = -5014.8
Depth At nearest Well = -5147
Computed Dip = 2.82401 on related structure
Re-Calculate DIP
Reset
Step 3. Porosity thickness.
Based on the depth of your well of -5014.8 ft, we recommend using the 10% Average Porosity map. The database estimates your net porosity thickness as 29.57
Porosity Thickness = 29.57 use 10% porosity
Reset
Next
Reset
Submit
Cancel
Java Applet Window

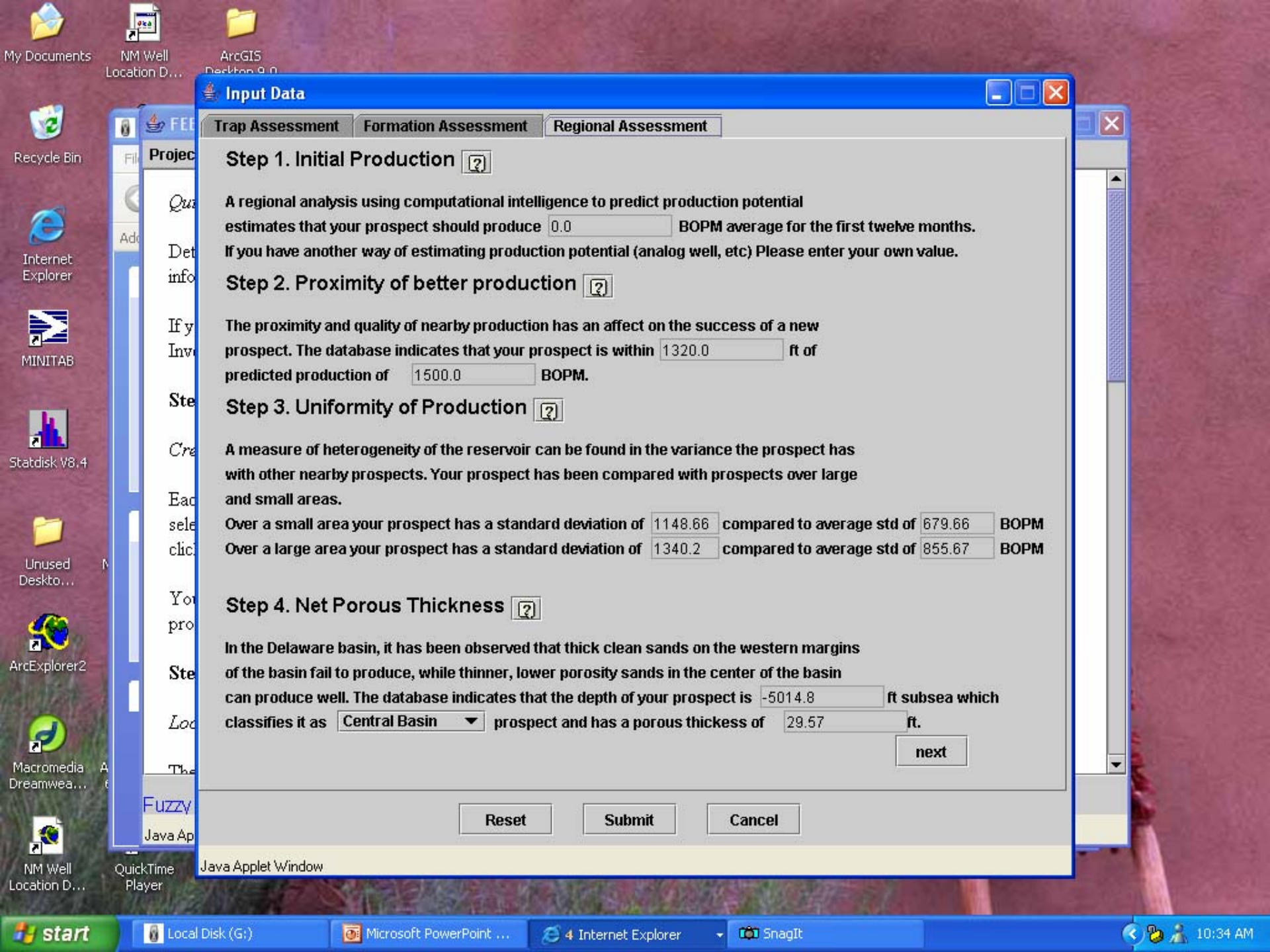

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 4. Stratigraphic Trap Search.
Using the Porosity Thickness from step 3, and searching the area adjacent to and up-dip of your prospect the following observations can be made:
A pinchout or thinout exists
Thickness variation up-dip in the area is insignificant
Thickness increases up-dip
No data/ Don't use in Analysis
Reset
Step 5. Structural strike analysis.
Based on your examination of the structure surrounding your prospect, indicate whether or not the prospect is on structural strike. Click here to view a pop-up map or use your own data.
Prospect is on Structural strike
Yes
No
Unable to Verify/ don't use in Analysis
Reset
Step 6. Thickness trends analysis
The database indicates that the area around your prospect has an average porosity thickness
of 29.58 with a standard deviation of 3.54 over a small area.
of 29.53 with a standard deviation of 8.34 over a large area.
Previous
Reset
Submit
Cancel
Java Applet Window

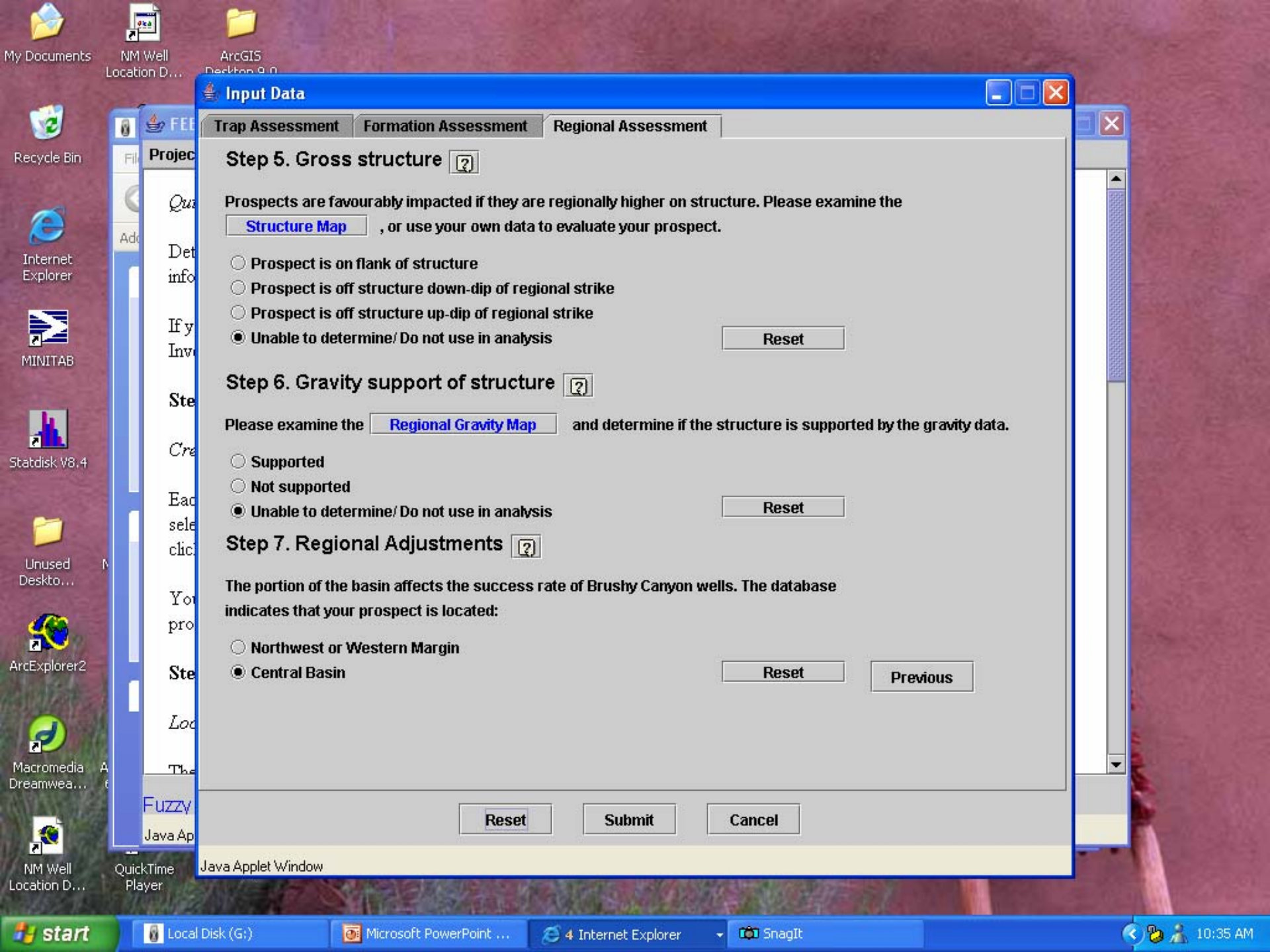

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 4. Stratigraphic Trap Search.
Using the Porosity Thickness from step 3, and searching the area adjacent to and up-dip of your prospect the following observations can be made:
A pinchout or thinout exists
Thickness variation up-dip in the area is insignificant
Thickness increases up-dip
No data/ Don't use in Analysis
Reset
Step 5. Structu
Message
Modified data has been saved to a secure file,
use the Inference and Summary menu to evaluate your prospect.
OK
Java Applet Window
Step 6. Thickness trends analysis
The database indicates that the area around your prospect has an
average porosity thickness
of 29.58 with a standard deviation of 3.54 over a small area.
of 29.53 with a standard deviation of 8.34 over a large area.
Previous
Reset
Submit
Cancel
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
FEE Tool D...
Windows M...
Inbox - Mic...
4 Interne...
2 Window...
trap3 - Paint
SnagIt
11:46 AM

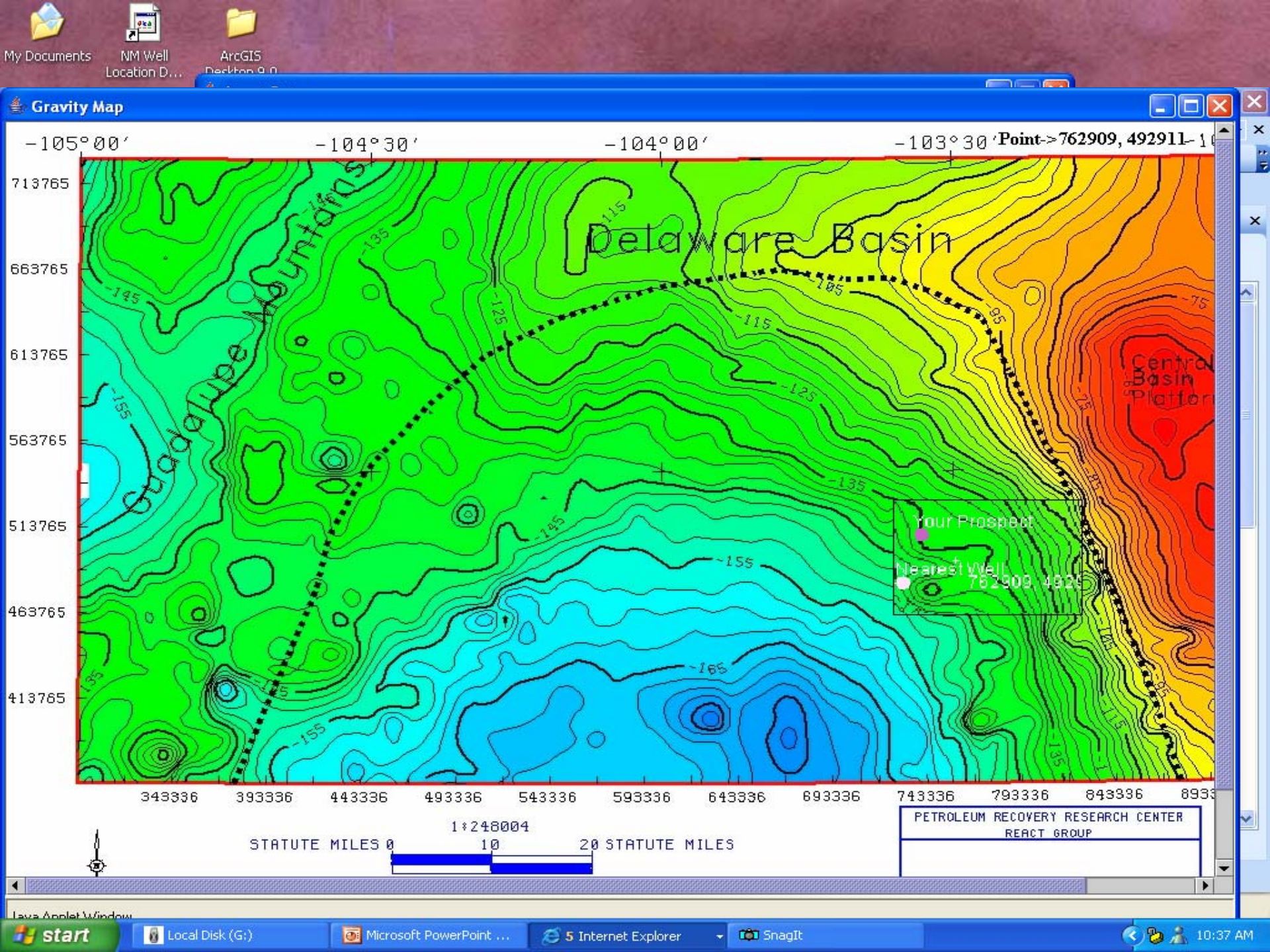

FEE Tool v1.0----user : sue Active project : Demo1
Location
Trap Info
Formation info
Regional info
Results
Help
Advanced
are being developed.This basic set of instructions will give the user
information on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal
Investigator Robert Balch by phone at (505) 835-5305 or by
E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project
select New from the Project Menu. Enter an appropriate name to identify the prospect and
click the
ok
button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete
prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window

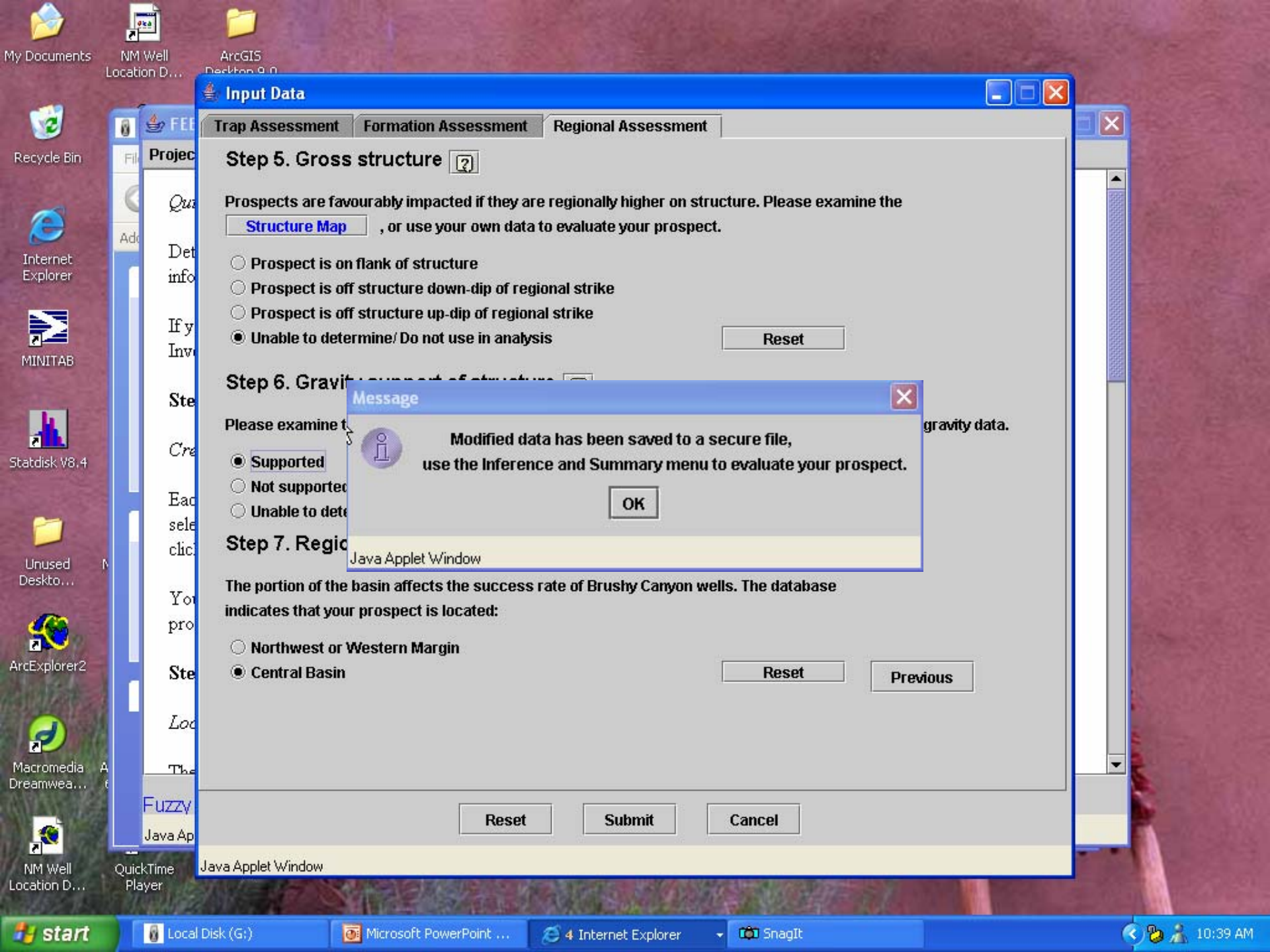

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 1. Quality of Source Rocks.
The database indicates that there are source rocks with Total Organic Carbon (TOC) of
0.766
% in the area of your prospect.
Step 2. Thermal Maturity of Source Rock.
Research indicates that the Lower Brushy Canyon is self sourced and of mixed oil and gas
prone Kerogen types. The database indicates that source rocks near your prospect are
Oil Window
ax, and Ro.
Database PI =
TAI =
Tmax =
Ro =
Message
Modified data has been saved to a secure file,
use the Inference and Summary menu to evaluate your prospect.
OK
Java Applet Window
Step 3. Migration Potential
The dip relationship between high quality source rocks proximal to your prospect was
evaluated. For this analysis only down dip source rocks were considered. The database indicates that your prosp...
does not h...
an up dip pinch-out or thin-out and is
1320.0
ft updip of rocks with TOC of
1.25
%
Reset
Reset
Submit
Cancel
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
10:31 AM

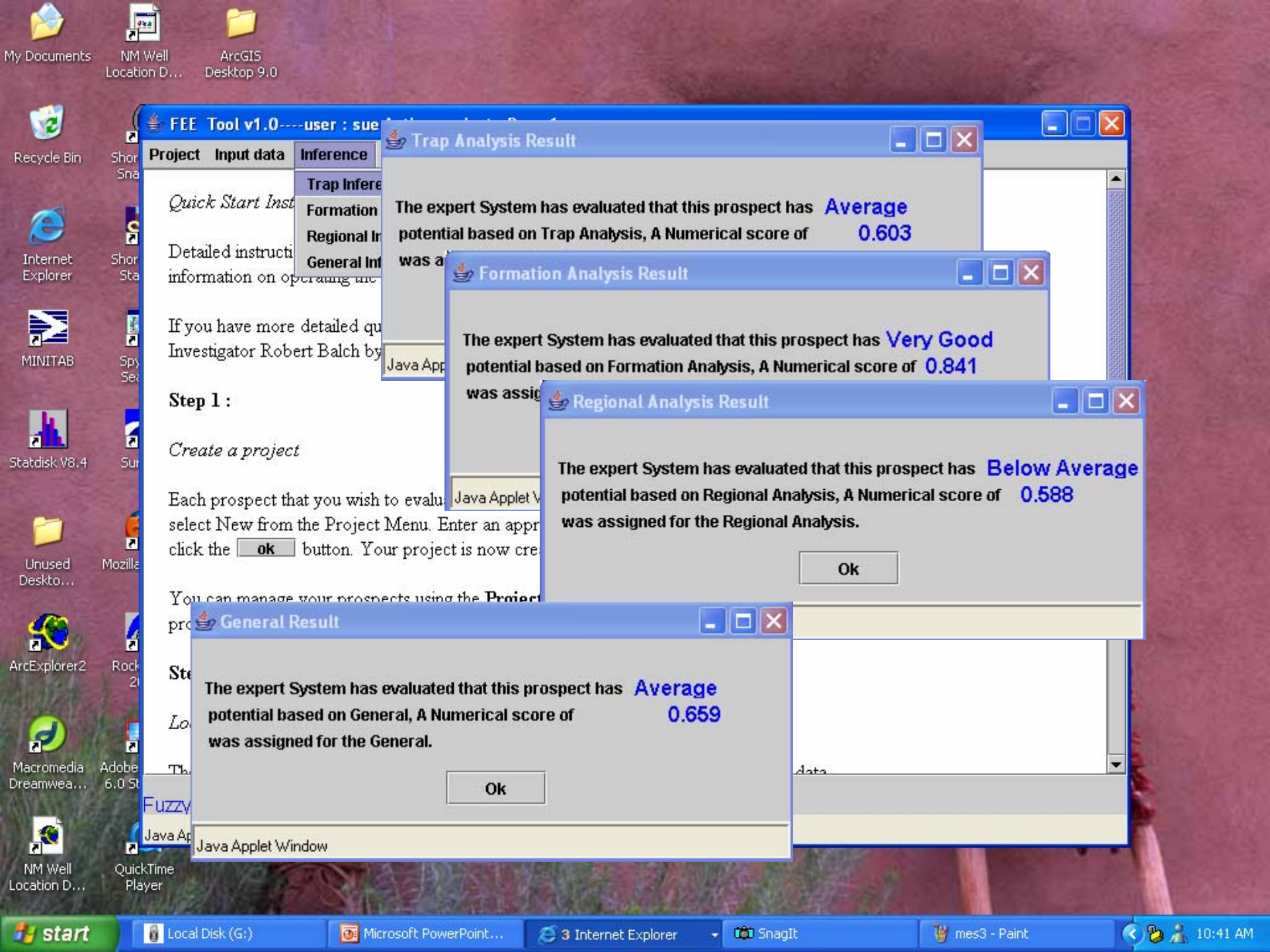

FEE Tool v1.0----user : sue Active project : Demo1
Location
Trap Info
Formation info
Regional info
Results
Help
Advanced
are being developed.This basic set of instructions will give the user
information on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal
Investigator Robert Balch by phone at (505) 835-5305 or by
E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project
select New from the Project Menu. Enter an appropriate name to identify the prospect and
click the
ok
button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete
prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window

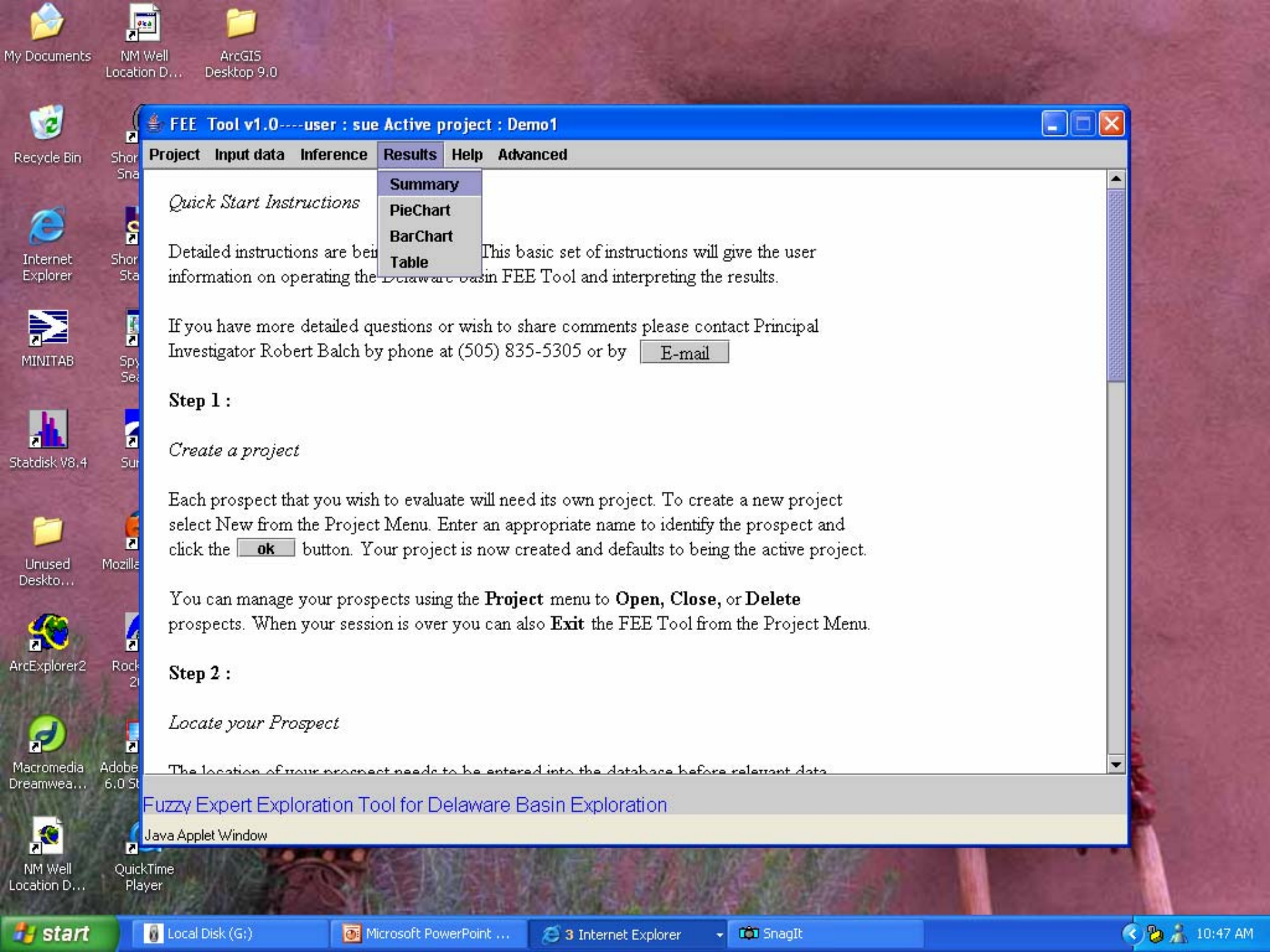

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 1. Initial Production
A regional analysis using computational intelligence to predict production potential
estimates that your prospect should produce 0.0 BOPM average for the first twelve months.
If you have another way of estimating production potential (analog well, etc) Please enter your own value.
Step 2. Proximity of better production
The proximity and quality of nearby production has an affect on the success of a new
prospect. The database indicates that your prospect is within 1320.0 ft of
predicted production of 1500.0 BOPM.
Step 3. Uniformity of Production
A measure of heterogeneity of the reservoir can be found in the variance the prospect has
with other nearby prospects. Your prospect has been compared with prospects over large
and small areas.
Over a small area your prospect has a standard deviation of 1148.66 compared to average std of 679.66 BOPM
Over a large area your prospect has a standard deviation of 1340.2 compared to average std of 855.67 BOPM
Step 4. Net Porous Thickness
In the Delaware basin, it has been observed that thick clean sands on the western margins
of the basin fail to produce, while thinner, lower porosity sands in the center of the basin
can produce well. The database indicates that the depth of your prospect is -5014.8 ft subsea which
classifies it as Central Basin prospect and has a porous thickess of 29.57 ft.
next
Reset
Submit
Cancel
Java Applet Window

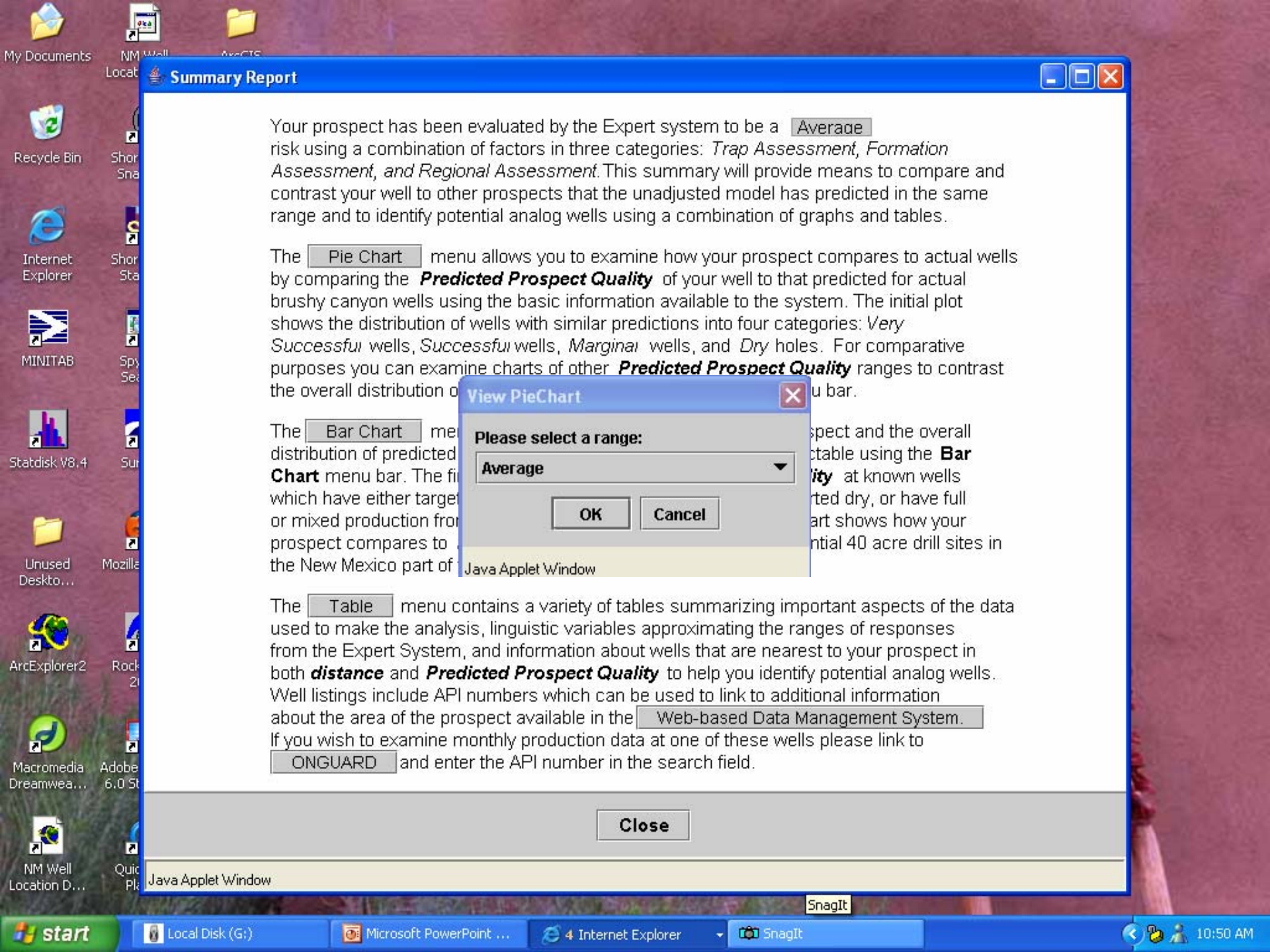

Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 5. Gross structure
Prospects are favourably impacted if they are regionally higher on structure. Please examine the
Structure Map
, or use your own data to evaluate your prospect.
Prospect is on flank of structure
Prospect is off structure down-dip of regional strike
Prospect is off structure up-dip of regional strike
Unable to determine/ Do not use in analysis
Reset
Step 6. Gravity support of structure
Please examine the
Regional Gravity Map
and determine if the structure is supported by the gravity data.
Supported
Not supported
Unable to determine/ Do not use in analysis
Reset
Step 7. Regional Adjustments
The portion of the basin affects the success rate of Brushy Canyon wells. The database indicates that your prospect is located:
Northwest or Western Margin
Central Basin
Reset
Previous
Reset
Submit
Cancel
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
10:35 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Gravity Map
-105°00'
-104°30'
-104°00'
-103°30'
Point->762909, 492911
713765
663765
613765
563765
513765
463765
413765
Delaware Basin
Guadalupe Mountains
Central Basin Platform
Your Prospect
Nearest Well
762909, 492
343336
393336
443336
493336
543336
593336
643336
693336
743336
793336
843336
1:248004
STATUTE MILES 0 10 20 STATUTE MILES
PETROLEUM RECOVERY RESEARCH CENTER
REACT GROUP
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoint ...
5 Internet Explorer
SnagIt
10:37 AM


Input Data
Trap Assessment
Formation Assessment
Regional Assessment
Step 5. Gross structure
Prospects are favourably impacted if they are regionally higher on structure. Please examine the
Structure Map
, or use your own data to evaluate your prospect.
Prospect is on flank of structure
Prospect is off structure down-dip of regional strike
Prospect is off structure up-dip of regional strike
Unable to determine/ Do not use in analysis
Reset
Step 6. Gravit
Please examine t
gravity data.
Supported
Not supported
Unable to dete
Step 7. Regio
The portion of the basin affects the success rate of Brushy Canyon wells. The database
indicates that your prospect is located:
Northwest or Western Margin
Central Basin
Reset
Previous
Reset
Submit
Cancel
Java Applet Window
Message
Modified data has been saved to a secure file,
use the Inference and Summary menu to evaluate your prospect.
OK
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
10:39 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0----user : sue
Project
Input data
Inference
Trap Infere
Formation
Regional In
General Inf
Quick Start Inst
Detailed instructi
information on operating the
If you have more detailed qu
Investigator Robert Balch by
Step 1 :
Create a project
Each prospect that you wish to evalu
select New from the Project Menu. Enter an appr
click the ok button. Your project is now cre
You can manage your prospects using the Project
pro
Ste
Lo
Th
data
Fuzzy
Java Ap
Java Applet Window
Trap Analysis Result
The expert System has evaluated that this prospect has Average
potential based on Trap Analysis, A Numerical score of 0.603
was a
Java App
Formation Analysis Result
The expert System has evaluated that this prospect has Very Good
potential based on Formation Analysis, A Numerical score of 0.841
was assig
Java Applet W
Regional Analysis Result
The expert System has evaluated that this prospect has Below Average
potential based on Regional Analysis, A Numerical score of 0.588
was assigned for the Regional Analysis.
Ok
General Result
The expert System has evaluated that this prospect has Average
potential based on General, A Numerical score of 0.659
was assigned for the General.
Ok
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoint...
3 Internet Explorer
SnagIt
mes3 - Paint
10:41 AM


FEE Tool v1.0----user : sue Active project : Demo1
Project
Input data
Inference
Results
Help
Advanced
Summary
PieChart
BarChart
Table
Quick Start Instructions
Detailed instructions are bei This basic set of instructions will give the user information on operating the Delaware Basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project select New from the Project Menu. Enter an appropriate name to identify the prospect and click the ok button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window

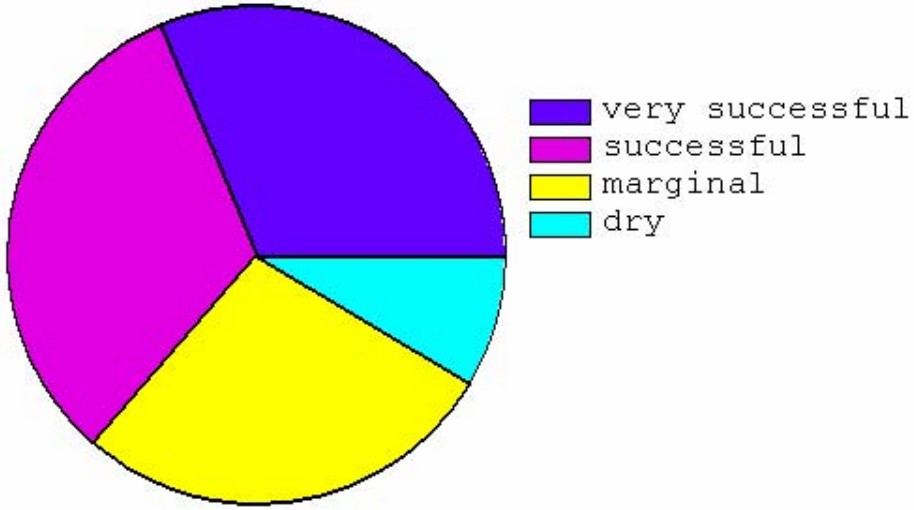

Summary Report
Your prospect has been evaluated by the Expert system to be a Average risk using a combination of factors in three categories: Trap Assessment, Formation Assessment, and Regional Assessment. This summary will provide means to compare and contrast your well to other prospects that the unadjusted model has predicted in the same range and to identify potential analog wells using a combination of graphs and tables.
The Pie Chart menu allows you to examine how your prospect compares to actual wells by comparing the Predicted Prospect Quality of your well to that predicted for actual brushy canyon wells using the basic information available to the system. The initial plot shows the distribution of wells with similar predictions into four categories: Very Successful wells, Successful wells, Marginal wells, and Dry holes. For comparative purposes you can examine charts of other Predicted Prospect Quality ranges to contrast the overall distribution o
u bar.
View PieChart
Please select a range:
Average
OK
Cancel
Java Applet Window
The Bar Chart me
spect and the overall distribution of predicted
ctable using the Bar Chart menu bar. The fi
ity at known wells which have either target
rted dry, or have full or mixed production fro
art shows how your prospect compares to
ntial 40 acre drill sites in the New Mexico part of
The Table menu contains a variety of tables summarizing important aspects of the data used to make the analysis, linguistic variables approximating the ranges of responses from the Expert System, and information about wells that are nearest to your prospect in both distance and Predicted Prospect Quality to help you identify potential analog wells. Well listings include API numbers which can be used to link to additional information about the area of the prospect available in the Web-based Data Management System. If you wish to examine monthly production data at one of these wells please link to ONGUARD and enter the API number in the search field.
Close
Java Applet Window
SnagIt
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
10:50 AM

Summary Report

Your prospect has been evaluated by the Expert system to be a Average
risk using a combination of factors in three categories: *Trap Assessment Formation*

Average

Wells with Average potential



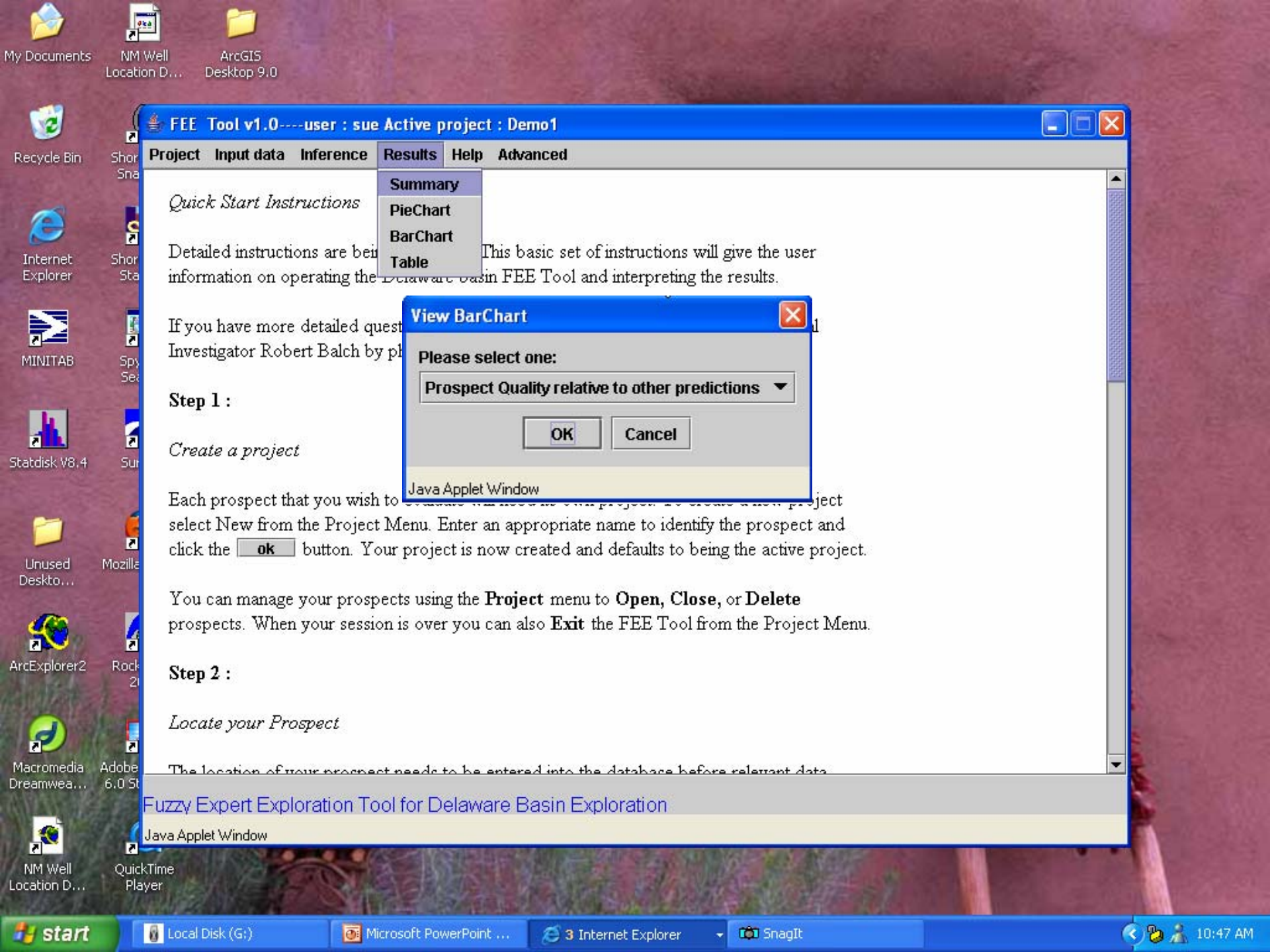
Close

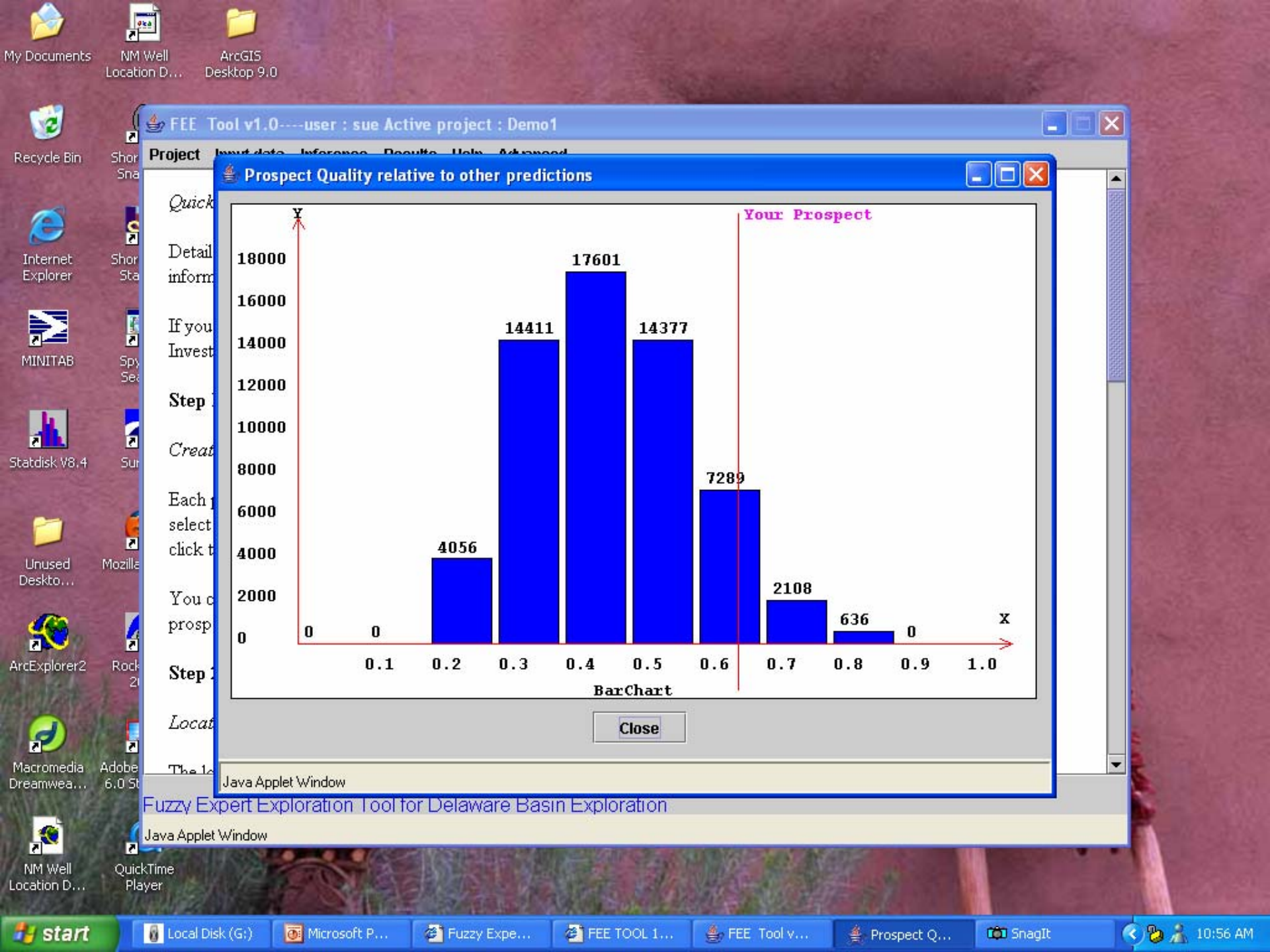
Java Applet Window

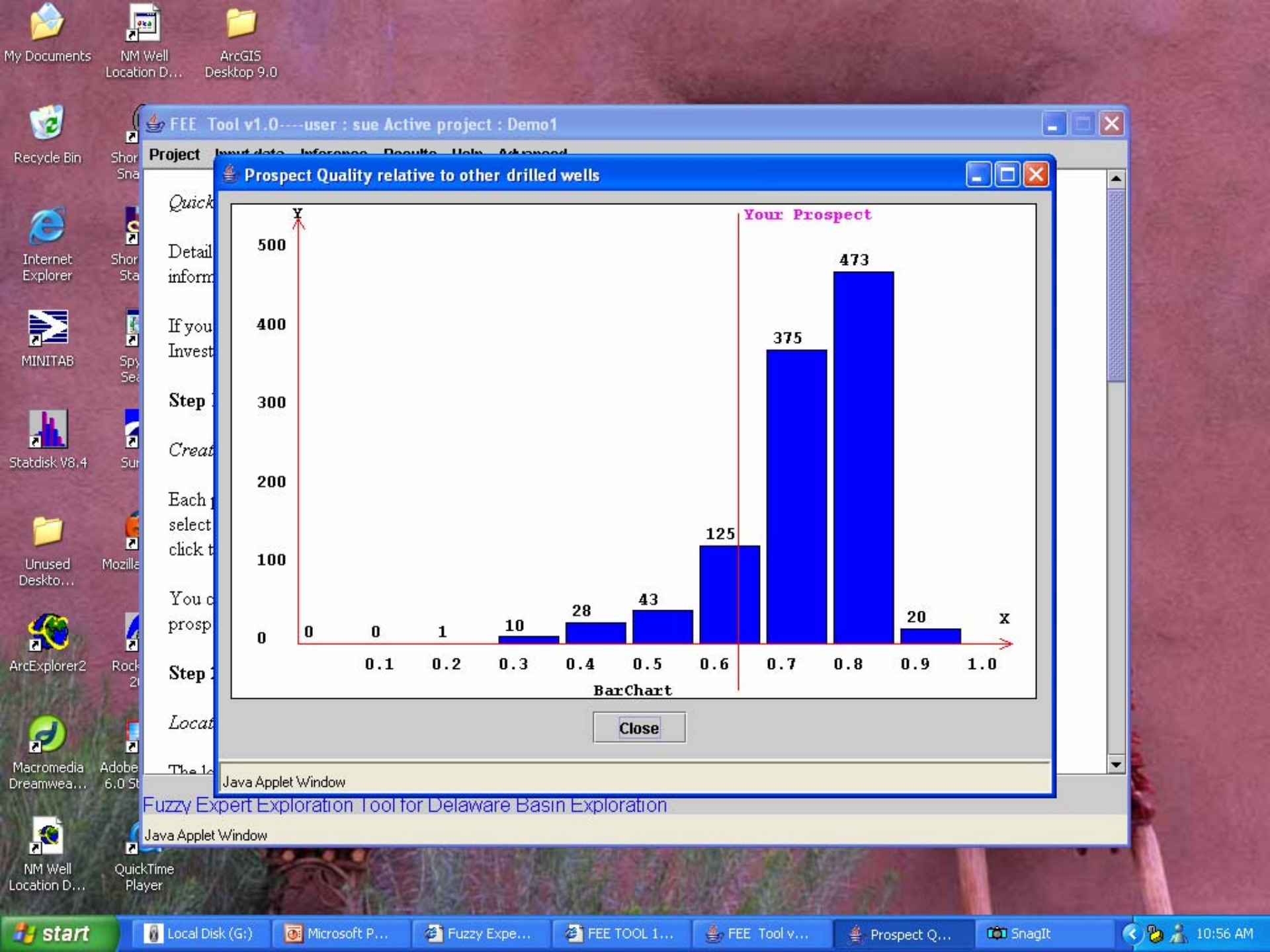
Close

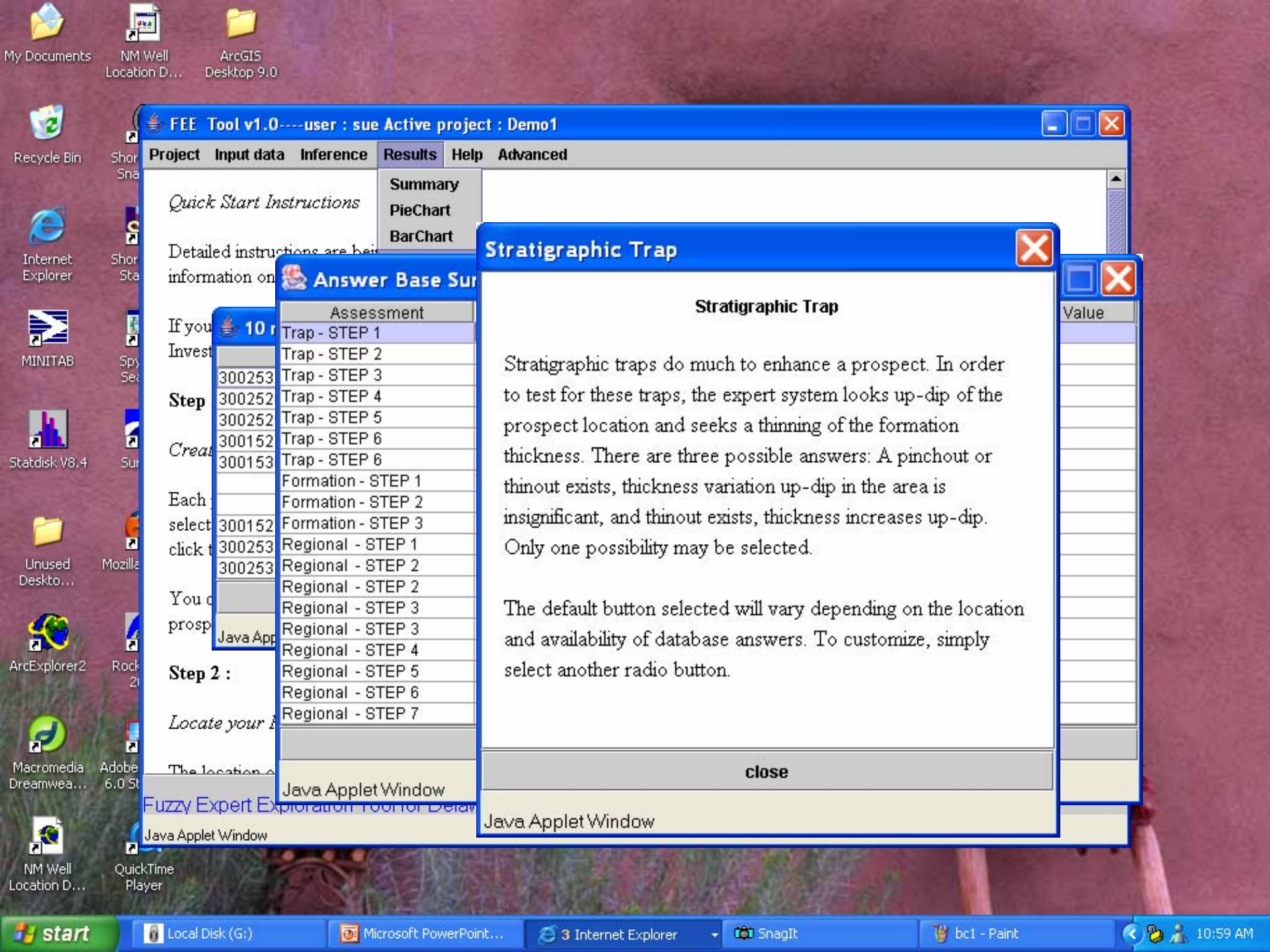
Java Applet Window

start | Local Disk (G:) | Microsoft PowerPoint ... | 5 Internet Explorer | 10:52 AM


FEE Tool v1.0----user : sue Active project : Demo1
Project
Input data
Inference
Results
Help
Advanced
Summary
PieChart
BarChart
Table
Quick Start Instructions
Detailed instructions are bei
This basic set of instructions will give the user
information on operating the
sin FEE Tool and interpreting the results.
If you have more detailed quest
l
Investigator Robert Balch by ph
Step 1 :
Create a project
Each prospect that you wish to
ject
select New from the Project Menu. Enter an appropriate name to identify the prospect and
click the ok button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete
prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
View BarChart
Please select one:
Prospect Quality relative to other predictions
OK
Cancel
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint ...
3 Internet Explorer
SnagIt
10:47 AM

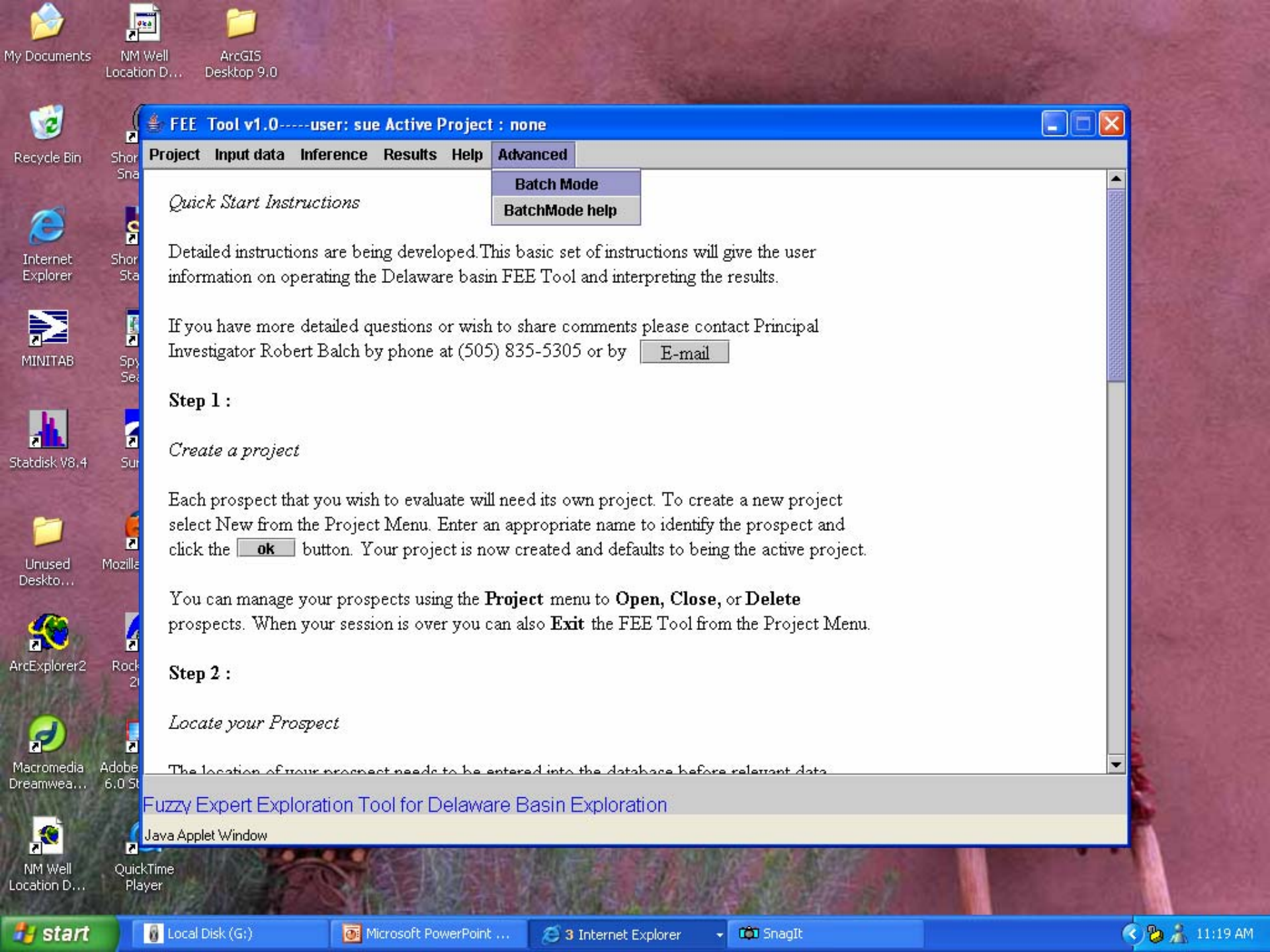

FEE Tool v1.0----user : sue Active project : Demo1
Project
Prospect Quality relative to other predictions
Y
X
Your Prospect
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
0
4056
14411
17601
14377
7289
2108
636
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
BarChart
Close
Java Applet Window
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window

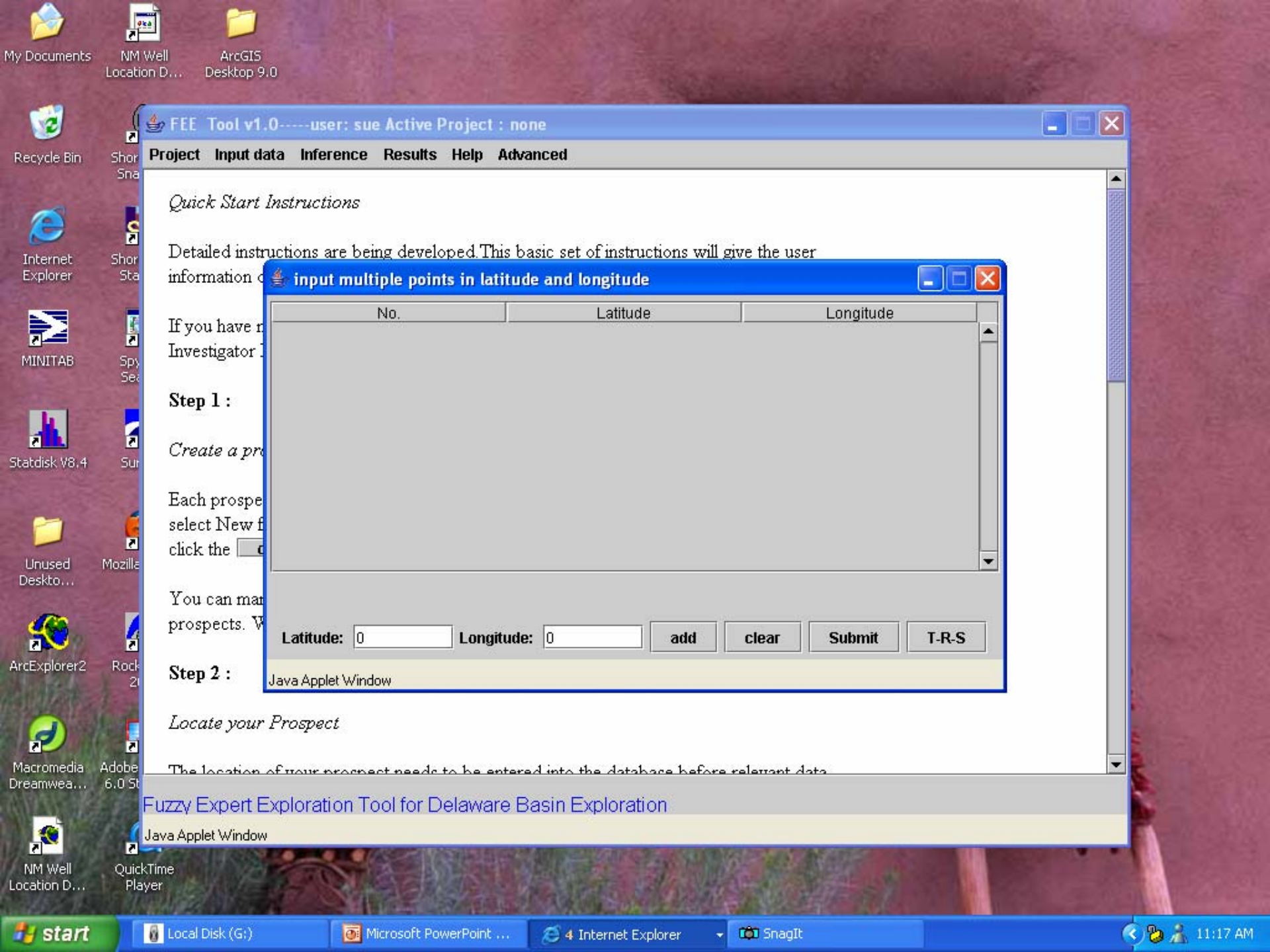

FEE Tool v1.0----user : sue Active project : Demo1
Project
Prospect Quality relative to other drilled wells
Y
X
Your Prospect
500
400
300
200
100
0
0
0
1
10
28
43
125
375
473
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
BarChart
Close
Java Applet Window
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window

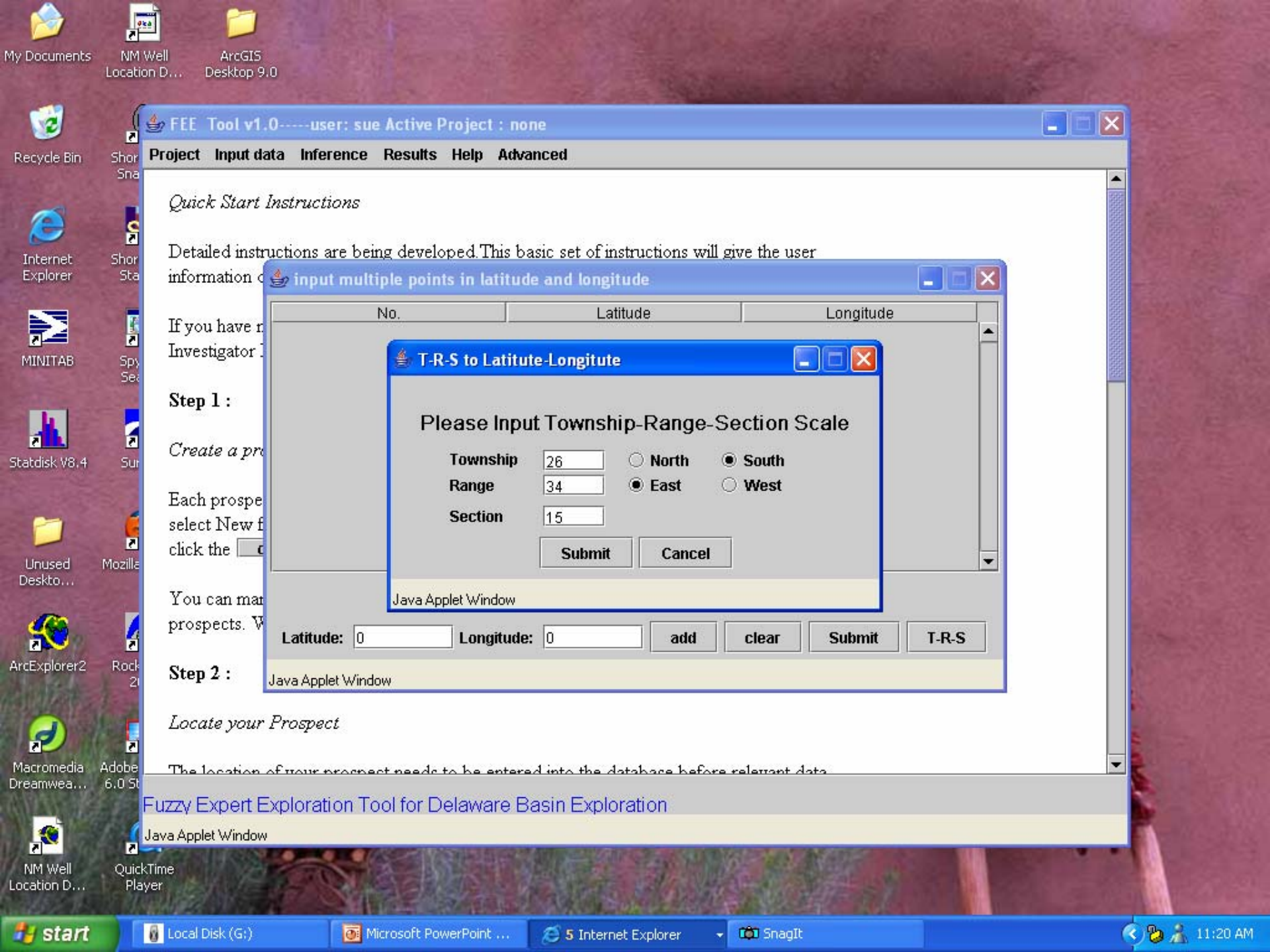

FEE Tool v1.0----user : sue Active project : Demo1
Project
Input data
Inference
Results
Help
Advanced
Summary
PieChart
BarChart
Quick Start Instructions
Step
Step 2 :
Answer Base Sur
Assessment
Trap - STEP 1
Trap - STEP 2
Trap - STEP 3
Trap - STEP 4
Trap - STEP 5
Trap - STEP 6
Trap - STEP 6
Formation - STEP 1
Formation - STEP 2
Formation - STEP 3
Regional - STEP 1
Regional - STEP 2
Regional - STEP 2
Regional - STEP 3
Regional - STEP 3
Regional - STEP 4
Regional - STEP 5
Regional - STEP 6
Regional - STEP 7
Java Applet Window
Value
Stratigraphic Trap
Stratigraphic Trap
Stratigraphic traps do much to enhance a prospect. In order to test for these traps, the expert system looks up-dip of the prospect location and seeks a thinning of the formation thickness. There are three possible answers: A pinchout or thinout exists, thickness variation up-dip in the area is insignificant, and thinout exists, thickness increases up-dip. Only one possibility may be selected.
The default button selected will vary depending on the location and availability of database answers. To customize, simply select another radio button.
close
Java Applet Window
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint...
3 Internet Explorer
SnagIt
bc1 - Paint
10:59 AM

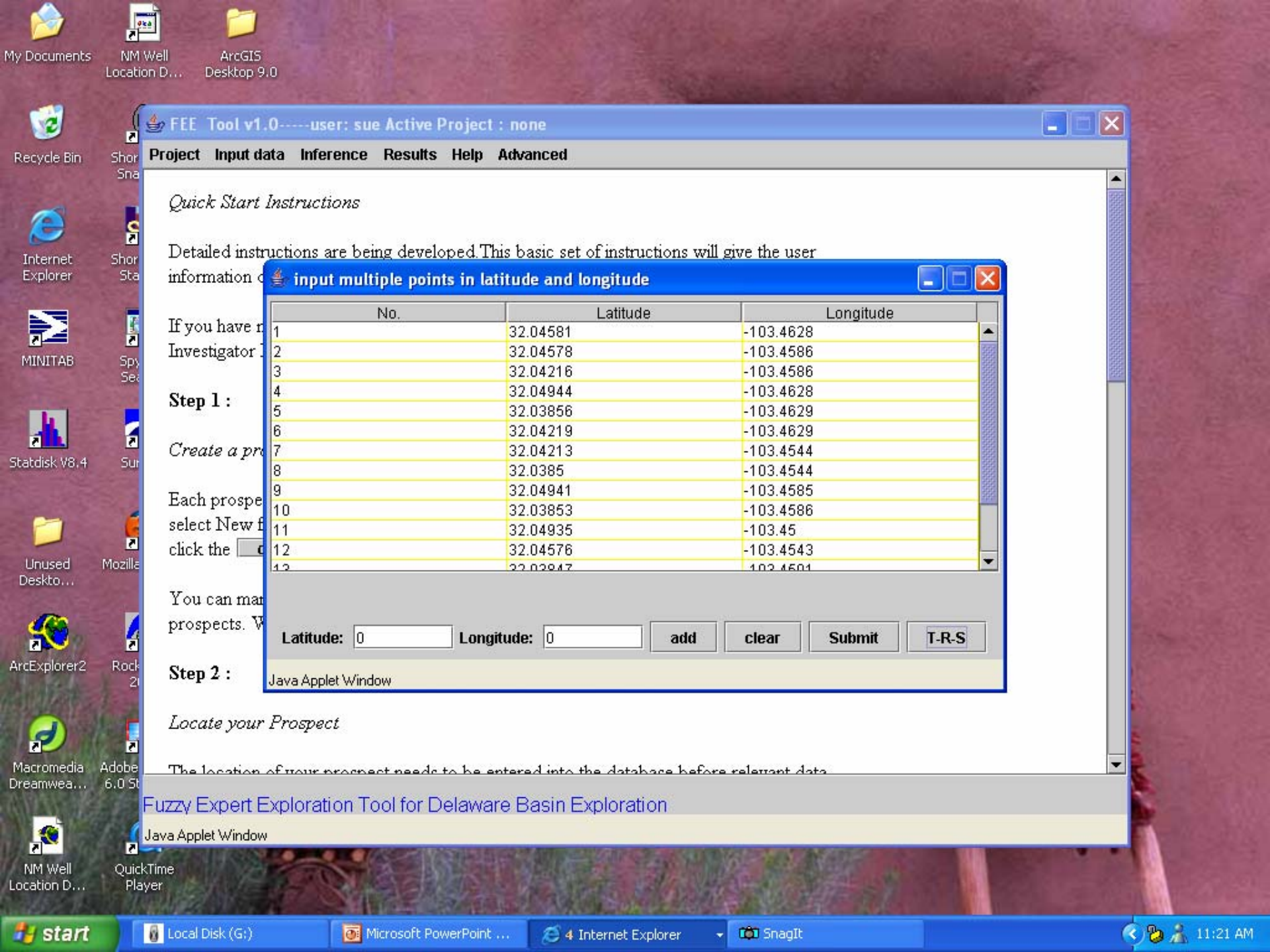
FEE Tool Demonstration

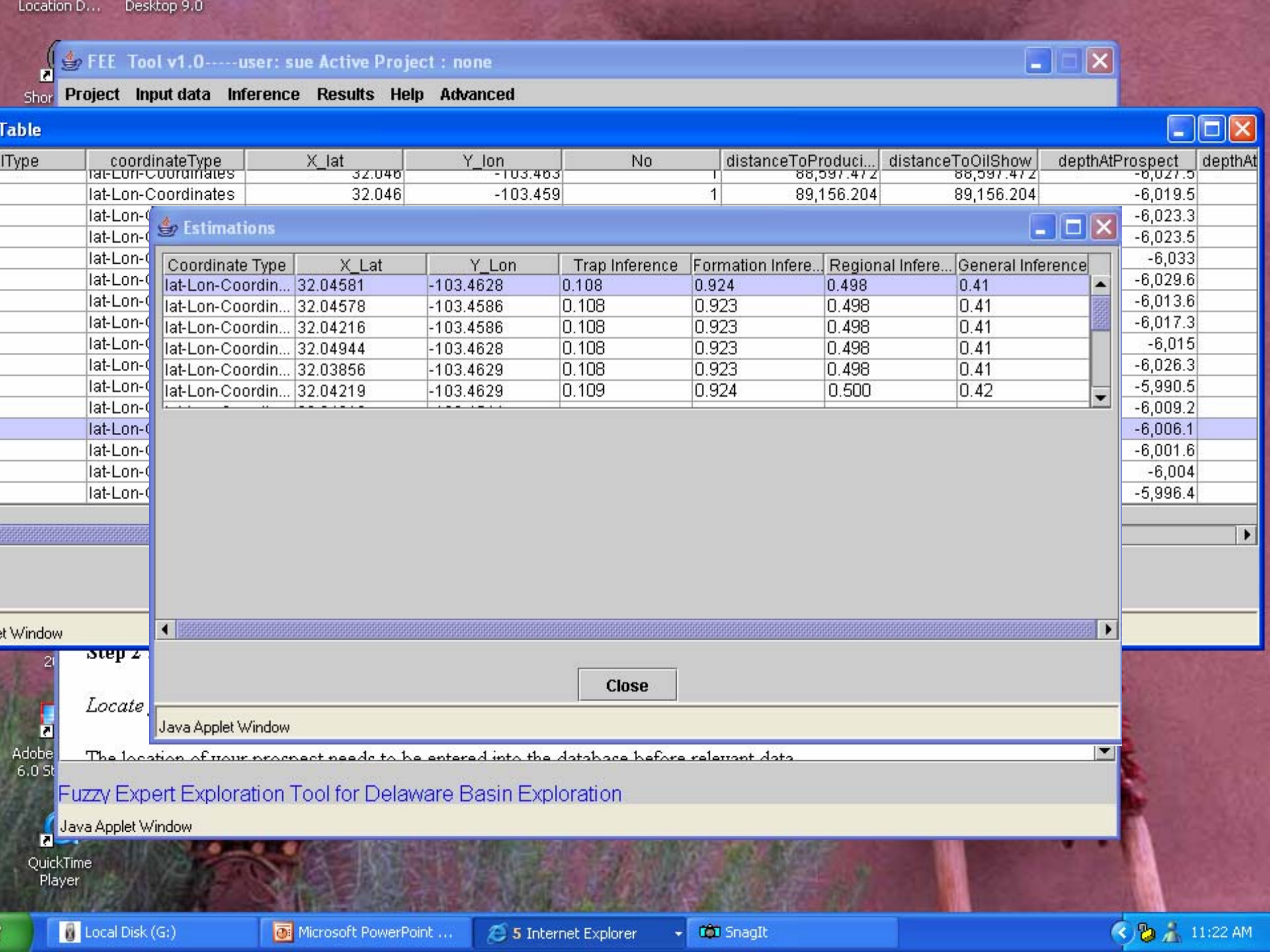
Batch Mode


FEE Tool v1.0-----user: sue Active Project : none
Project
Input data
Inference
Results
Help
Advanced
Batch Mode
BatchMode help
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user information on operating the Delaware basin FEE Tool and interpreting the results.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by
E-mail
Step 1 :
Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project select New from the Project Menu. Enter an appropriate name to identify the prospect and click the
ok
button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 :
Locate your Prospect
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0-----user: sue Active Project : none
Project
Input data
Inference
Results
Help
Advanced
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user
information
If you have
Investigator
Step 1 :
Create a pr
Each prospe
select New f
click the
You can mar
prospects. W
Step 2 :
Locate your Prospect
input multiple points in latitude and longitude
No.
Latitude
Longitude
Latitude: 0
Longitude: 0
add
clear
Submit
T-R-S
Java Applet Window
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
11:17 AM


FEE Tool v1.0-----user: sue Active Project : none
Project
Input data
Inference
Results
Help
Advanced
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user
information
If you have
Investigator
Step 1 :
Create a pr
Each prospe
select New f
click the
You can mar
prospects. W
Step 2 :
Locate your Prospect
The location of your prospect needs to be entered into the database before relevant data
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
input multiple points in latitude and longitude
No.
Latitude
Longitude
T-R-S to Latitute-Longitute
Please Input Township-Range-Section Scale
Township
26
North
South
Range
34
East
West
Section
15
Submit
Cancel
Java Applet Window
Latitude:
0
Longitude:
0
add
clear
Submit
T-R-S
Java Applet Window
My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
start
Local Disk (G:)
Microsoft PowerPoint ...
5 Internet Explorer
SnagIt
11:20 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Internet Explorer
MINITAB
Statdisk V8.4
Unused Deskto...
ArcExplorer2
Macromedia Dreamwea...
NM Well Location D...
QuickTime Player
FEE Tool v1.0-----user: sue Active Project : none
Project
Input data
Inference
Results
Help
Advanced
Quick Start Instructions
Detailed instructions are being developed.This basic set of instructions will give the user
information
If you have
Investigator
Step 1 :
Create a pr
Each prospe
select New
click the
You can ma
prospects.
Step 2 :
Locate your Prospect
input multiple points in latitude and longitude
No.
Latitude
Longitude
1 32.04581 -103.4628
2 32.04578 -103.4586
3 32.04216 -103.4586
4 32.04944 -103.4628
5 32.03856 -103.4629
6 32.04219 -103.4629
7 32.04213 -103.4544
8 32.0385 -103.4544
9 32.04941 -103.4585
10 32.03853 -103.4586
11 32.04935 -103.45
12 32.04576 -103.4543
Latitude: 0
Longitude: 0
add
clear
Submit
T-R-S
Java Applet Window
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoint ...
4 Internet Explorer
SnagIt
11:21 AM


FEE Tool v1.0-----user: sue Active Project : none
Project Input data Inference Results Help Advanced
Table
lType coordinateType X_lat Y_lon No distanceToProduci... distanceToOilShow depthAtProspect depthAt
lat-Lon-Coordinates 32.046 -103.459 1 89,156.204 89,156.204 -6,019.5
-6,023.3
-6,023.5
-6,033
-6,029.6
-6,013.6
-6,017.3
-6,015
-6,026.3
-5,990.5
-6,009.2
-6,006.1
-6,001.6
-6,004
-5,996.4
Estimations
Coordinate Type X_Lat Y_Lon Trap Inference Formation Infere... Regional Infere... General Inference
lat-Lon-Coordin... 32.04581 -103.4628 0.108 0.924 0.498 0.41
lat-Lon-Coordin... 32.04578 -103.4586 0.108 0.923 0.498 0.41
lat-Lon-Coordin... 32.04216 -103.4586 0.108 0.923 0.498 0.41
lat-Lon-Coordin... 32.04944 -103.4628 0.108 0.923 0.498 0.41
lat-Lon-Coordin... 32.03856 -103.4629 0.108 0.923 0.498 0.41
lat-Lon-Coordin... 32.04219 -103.4629 0.109 0.924 0.500 0.42
Close
Java Applet Window
Step 2
Locate
Fuzzy Expert Exploration Tool for Delaware Basin Exploration
Java Applet Window
Local Disk (G:)
Microsoft PowerPoint ...
5 Internet Explorer
SnagIt
11:22 AM

FEE Tool Demonstration

Devonian FEE Tool features

Fuzzy Expert Exploration Tool

Incomplete or sparse information on types of data such as geologic or formation characteristics introduces a high level of risk for oil exploration and development projects. "Expert" systems developed and used in several disciplines and industries have demonstrated beneficial results. A state-of-the-art exploration "expert" tool, relying on a computerized database and computer maps generated by neural networks, is being developed through the use of "fuzzy" logic, a relatively new mathematical treatment of imprecise or non-explicit parameters and values. Oil prospecting risk can be reduced with the use of a properly developed and validated "Fuzzy Expert Exploration (FEE) Tool."

The Fuzzy Expert Exploration Tool will eventually be generalized so that users in any part of the world will be able to add their own knowledge and data and make rapid evaluations of a large number of potential drilling sites in a systematic and consistent manner via the internet. A case study of the Lower Brushy Canyon formation of the Delaware basin, New Mexico is being used to verify the software and test the potential of the FEE Tool.

Below are links instructing potential users how to access and utilize the system for the Delaware Basin specific FEE Tool, to related regional data, and to collaterally developed on-line neural network software and input selection code utilizing fuzzy logic.

Delaware Basin FEE Tool

Download the User Manual .(about 3.8MB)

A password protected account is required to use the FEE tool while it is in beta testing.

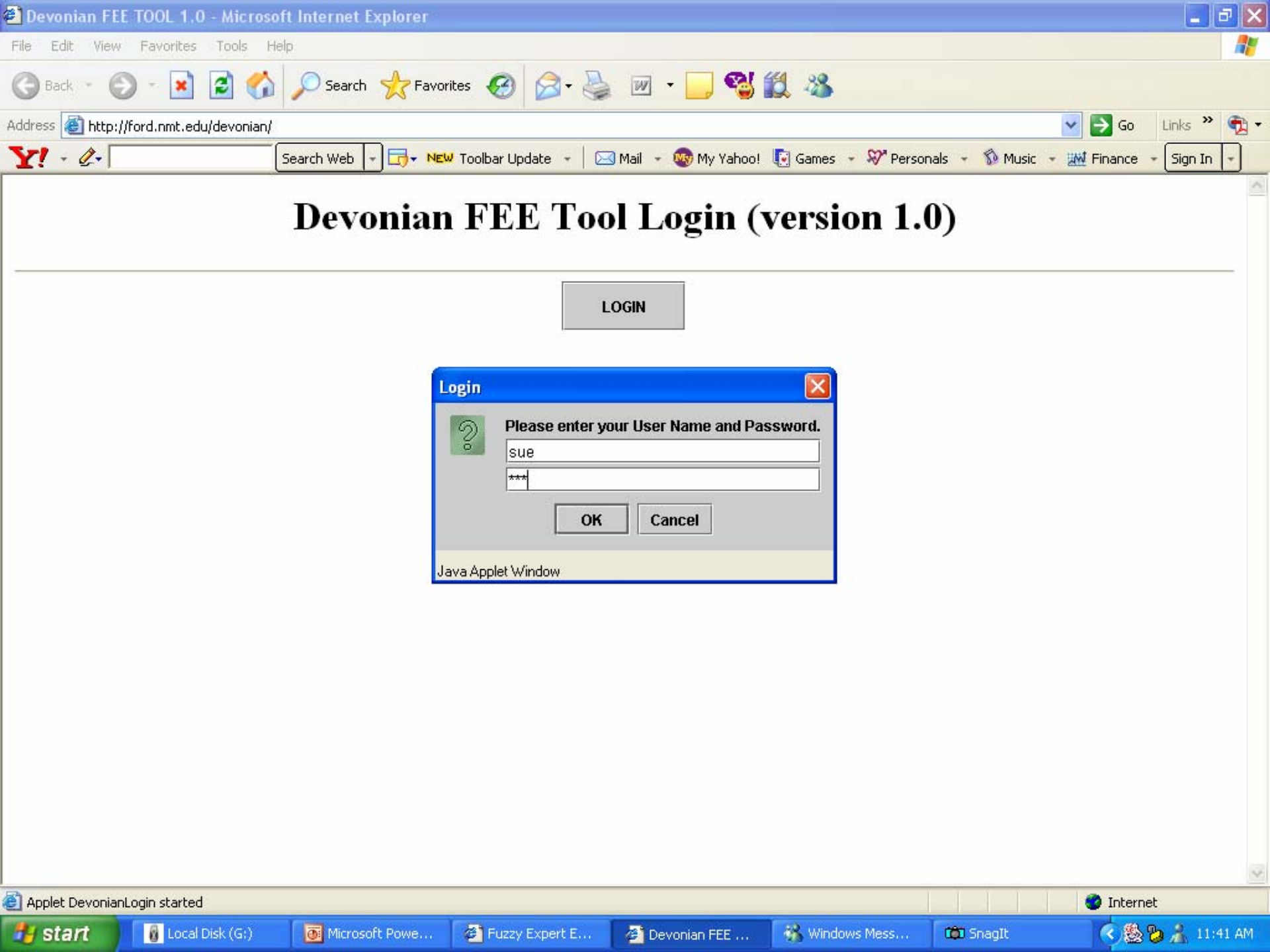
E-mail Principal Investigator Robert Balch, , call (505) 835-5305 for information, or register on line.

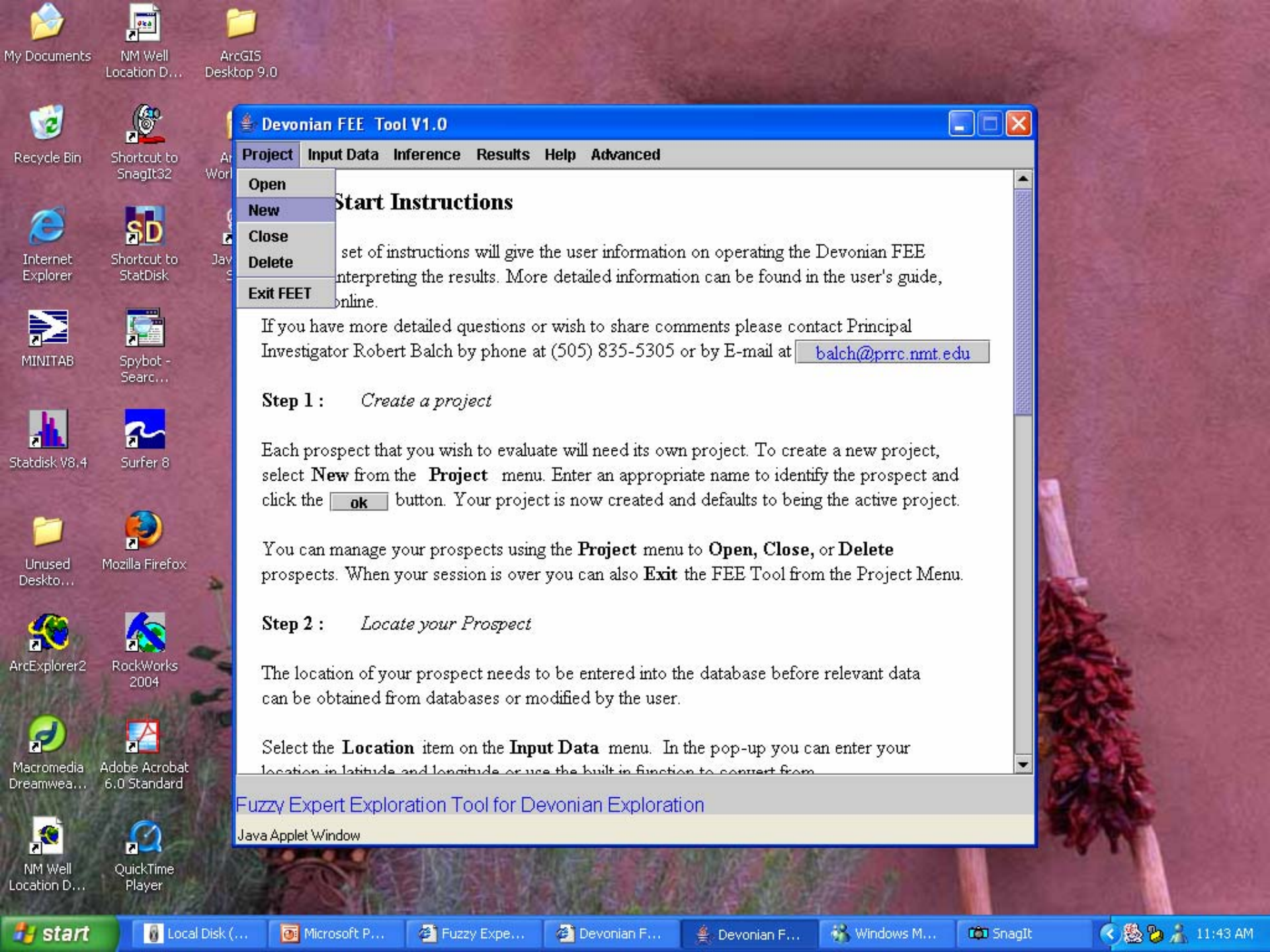
Download the off-line version (about 12.9 MB).(Need Java on your computer to run)

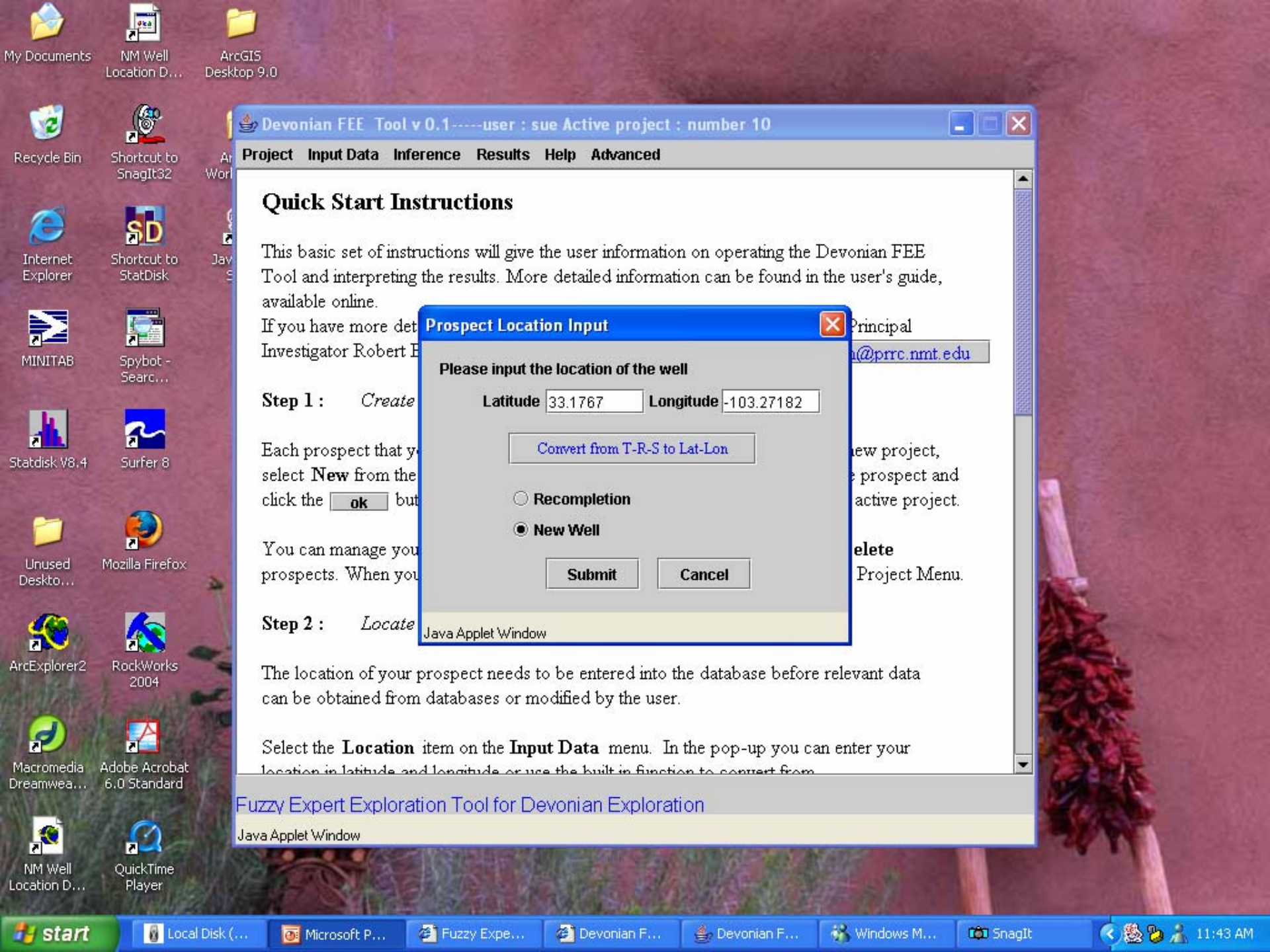
Devonian FEE Tool

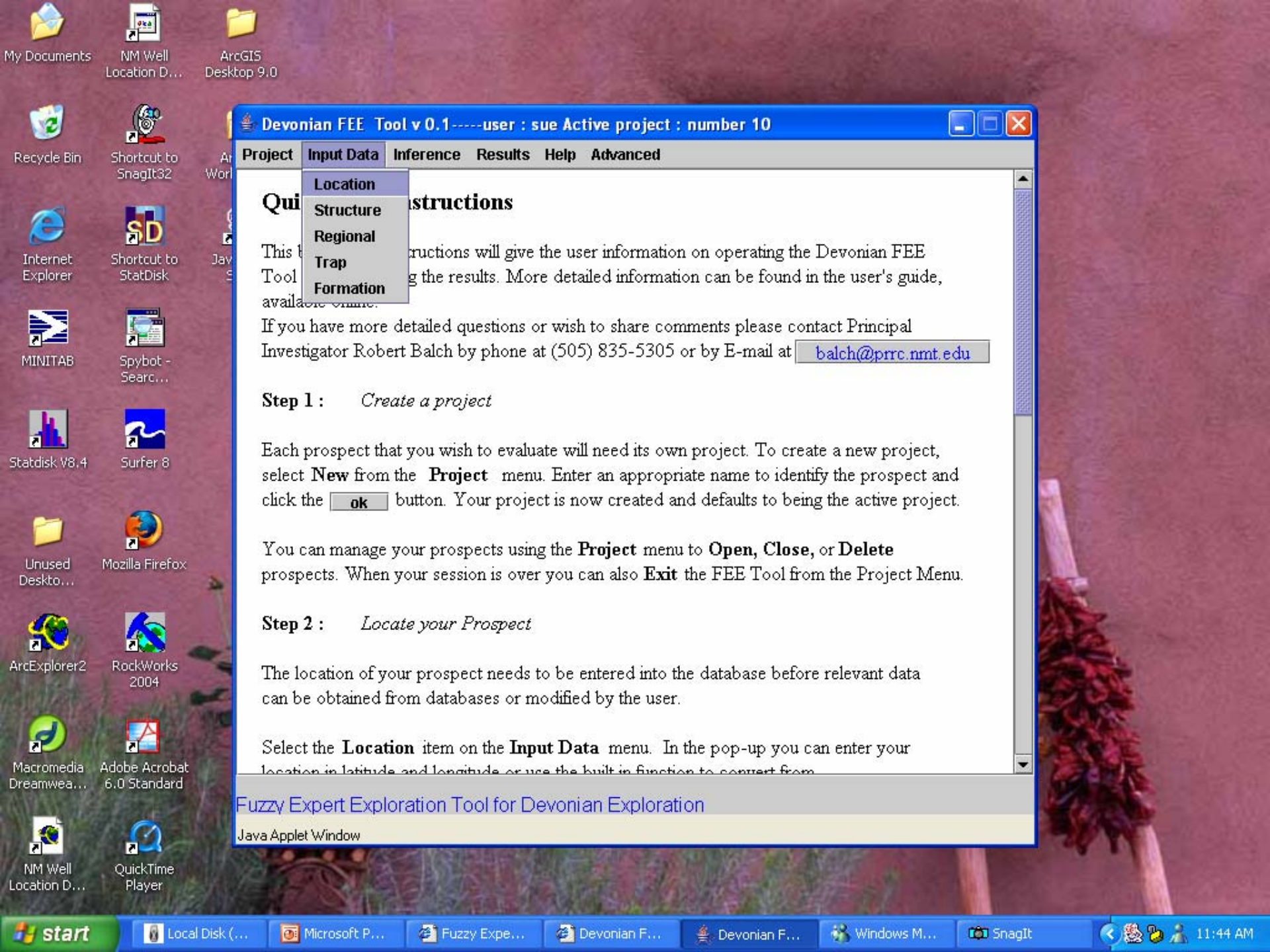
Download the User Manual .(about 3.8MB)

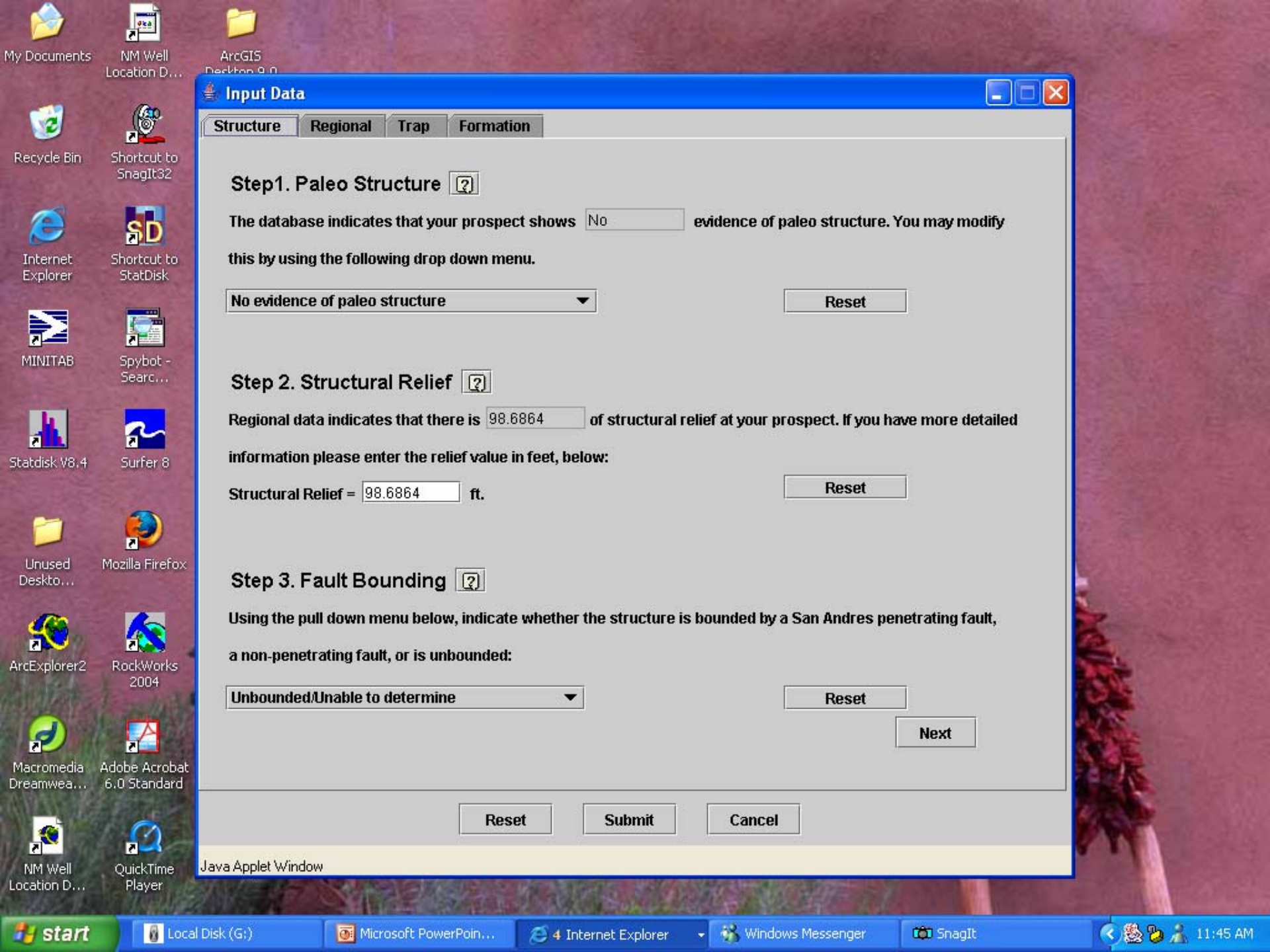
A password protected account is required to use the FEE tool while it is in beta testing

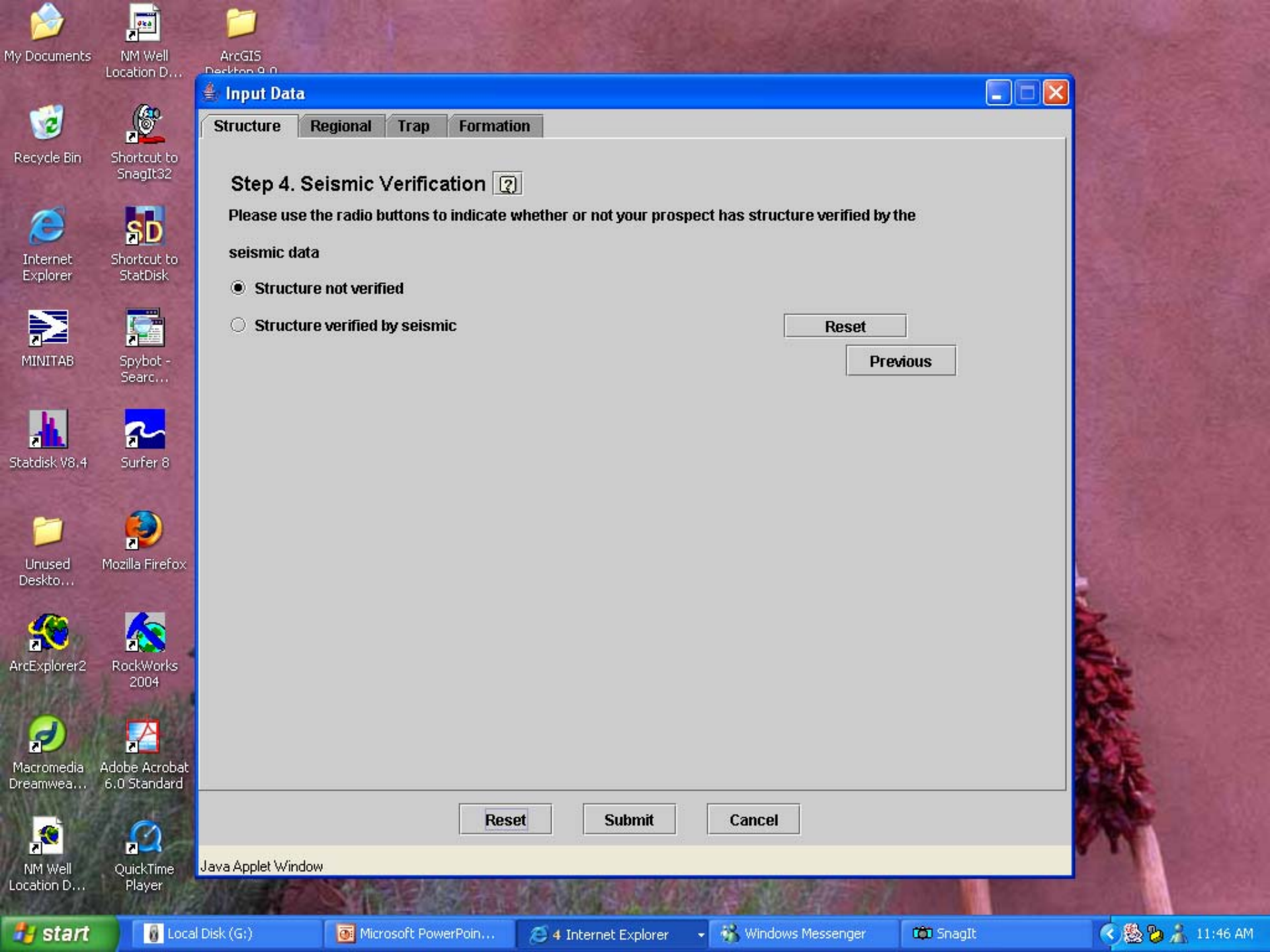

Devonian FEE TOOL 1.0 - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://ford.nmt.edu/devonian/
Go Links
Search Web Toolbar Update Mail My Yahoo! Games Personals Music Finance Sign In
Devonian FEE Tool Login (version 1.0)
LOGIN
Login
Please enter your User Name and Password.
sue
***
OK
Cancel
Java Applet Window
Applet DevonianLogin started
Internet
start
Local Disk (G:)
Microsoft Powe...
Fuzzy Expert E...
Devonian FEE ...
Windows Mess...
SnagIt
11:41 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Shortcut to SnagIt32
Internet Explorer
Shortcut to StatDisk
MINITAB
Spybot - Searc...
Statdisk V8.4
Surfer 8
Unused Deskto...
Mozilla Firefox
ArcExplorer2
RockWorks 2004
Macromedia Dreamwea...
Adobe Acrobat 6.0 Standard
NM Well Location D...
QuickTime Player
Devonian FEE Tool V1.0
Project
Input Data
Inference
Results
Help
Advanced
Open
New
Close
Delete
Exit FEET
Start Instructions
set of instructions will give the user information on operating the Devonian FEE
nterpreting the results. More detailed information can be found in the user's guide,
nline.
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail at balch@prrc.nmt.edu
Step 1 : Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project, select New from the Project menu. Enter an appropriate name to identify the prospect and click the ok button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 : Locate your Prospect
The location of your prospect needs to be entered into the database before relevant data can be obtained from databases or modified by the user.
Select the Location item on the Input Data menu. In the pop-up you can enter your
Fuzzy Expert Exploration Tool for Devonian Exploration
Java Applet Window
start
Local Disk (...
Microsoft P...
Fuzzy Expe...
Devonian F...
Devonian F...
Windows M...
SnagIt
11:43 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Shortcut to SnagIt32
Internet Explorer
Shortcut to StatDisk
MINITAB
Spybot - Searc...
Statdisk V8.4
Surfer 8
Unused Deskto...
Mozilla Firefox
ArcExplorer2
RockWorks 2004
Macromedia Dreamwea...
Adobe Acrobat 6.0 Standard
NM Well Location D...
QuickTime Player
Devonian FEE Tool v 0.1-----user : sue Active project : number 10
Project
Input Data
Inference
Results
Help
Advanced
Quick Start Instructions
This basic set of instructions will give the user information on operating the Devonian FEE Tool and interpreting the results. More detailed information can be found in the user's guide, available online.
If you have more det
Principal Investigator Robert E
@prrc.nmt.edu
Step 1 :
Create
Each prospect that y
new project, select New from the
prospect and click the ok but
active project.
You can manage you
elete prospects. When you
Project Menu.
Step 2 :
Locate
The location of your prospect needs to be entered into the database before relevant data can be obtained from databases or modified by the user.
Select the Location item on the Input Data menu. In the pop-up you can enter your
Prospect Location Input
Please input the location of the well
Latitude 33.1767
Longitude -103.27182
Convert from T-R-S to Lat-Lon
Recompletion
New Well
Submit
Cancel
Java Applet Window
Fuzzy Expert Exploration Tool for Devonian Exploration
Java Applet Window
start
Local Disk (...
Microsoft P...
Fuzzy Expe...
Devonian F...
Devonian F...
Windows M...
SnagIt
11:43 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Shortcut to SnagIt32
Internet Explorer
Shortcut to StatDisk
MINITAB
Spybot - Searc...
Statdisk V8.4
Surfer 8
Unused Deskto...
Mozilla Firefox
ArcExplorer2
RockWorks 2004
Macromedia Dreamwea...
Adobe Acrobat 6.0 Standard
NM Well Location D...
QuickTime Player
Devonian FEE Tool v 0.1-----user : sue Active project : number 10
Project
Input Data
Inference
Results
Help
Advanced
Location
Structure
Regional
Trap
Formation
Qui structions
This t ructions will give the user information on operating the Devonian FEE Tool g the results. More detailed information can be found in the user's guide, availa
If you have more detailed questions or wish to share comments please contact Principal Investigator Robert Balch by phone at (505) 835-5305 or by E-mail at balch@prrc.nmt.edu
Step 1 : Create a project
Each prospect that you wish to evaluate will need its own project. To create a new project, select New from the Project menu. Enter an appropriate name to identify the prospect and click the ok button. Your project is now created and defaults to being the active project.
You can manage your prospects using the Project menu to Open, Close, or Delete prospects. When your session is over you can also Exit the FEE Tool from the Project Menu.
Step 2 : Locate your Prospect
The location of your prospect needs to be entered into the database before relevant data can be obtained from databases or modified by the user.
Select the Location item on the Input Data menu. In the pop-up you can enter your
Fuzzy Expert Exploration Tool for Devonian Exploration
Java Applet Window
start
Local Disk (...
Microsoft P...
Fuzzy Expe...
Devonian F...
Devonian F...
Windows M...
SnagIt
11:44 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Shortcut to SnagIt32
Internet Explorer
Shortcut to StatDisk
MINITAB
Spybot - Searc...
Statdisk V8.4
Surfer 8
Unused Deskto...
Mozilla Firefox
ArcExplorer2
RockWorks 2004
Macromedia Dreamwea...
Adobe Acrobat 6.0 Standard
NM Well Location D...
QuickTime Player
Input Data
Structure
Regional
Trap
Formation
Step1. Paleo Structure
The database indicates that your prospect shows No evidence of paleo structure. You may modify this by using the following drop down menu.
No evidence of paleo structure
Reset
Step 2. Structural Relief
Regional data indicates that there is 98.6864 of structural relief at your prospect. If you have more detailed information please enter the relief value in feet, below:
Structural Relief = 98.6864 ft.
Reset
Step 3. Fault Bounding
Using the pull down menu below, indicate whether the structure is bounded by a San Andres penetrating fault, a non-penetrating fault, or is unbounded:
Unbounded/Unable to determine
Reset
Next
Reset
Submit
Cancel
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoin...
4 Internet Explorer
Windows Messenger
SnagIt
11:45 AM


My Documents
NM Well Location D...
ArcGIS Desktop 9.0
Recycle Bin
Shortcut to SnagIt32
Internet Explorer
Shortcut to StatDisk
MINITAB
Spybot - Searc...
Statdisk V8.4
Surfer 8
Unused Deskto...
Mozilla Firefox
ArcExplorer2
RockWorks 2004
Macromedia Dreamwea...
Adobe Acrobat 6.0 Standard
NM Well Location D...
QuickTime Player
Input Data
Structure
Regional
Trap
Formation
Step 4. Seismic Verification
Please use the radio buttons to indicate whether or not your prospect has structure verified by the seismic data
Structure not verified
Structure verified by seismic
Reset
Previous
Reset
Submit
Cancel
Java Applet Window
start
Local Disk (G:)
Microsoft PowerPoin...
4 Internet Explorer
Windows Messenger
SnagIt
11:46 AM

Testing

Introduction

- In any project it is important to test the robustness of methodologies and results.
- For software projects the functionality of the software is also an important concern.
- These two components are termed Validation and Verification.

Validation and Verification

- *Validation* is a computer science term (Gupta, 1990) meaning:

"*Each level of specification and deliverable code are traceable to a superior specification, that is, the specification or code fully and exclusively implements the requirement of the superior specification*"

  - In layman terms, the software is true to its design.

Validation and Verification

- *Verification* is concerned with testing to determine if:

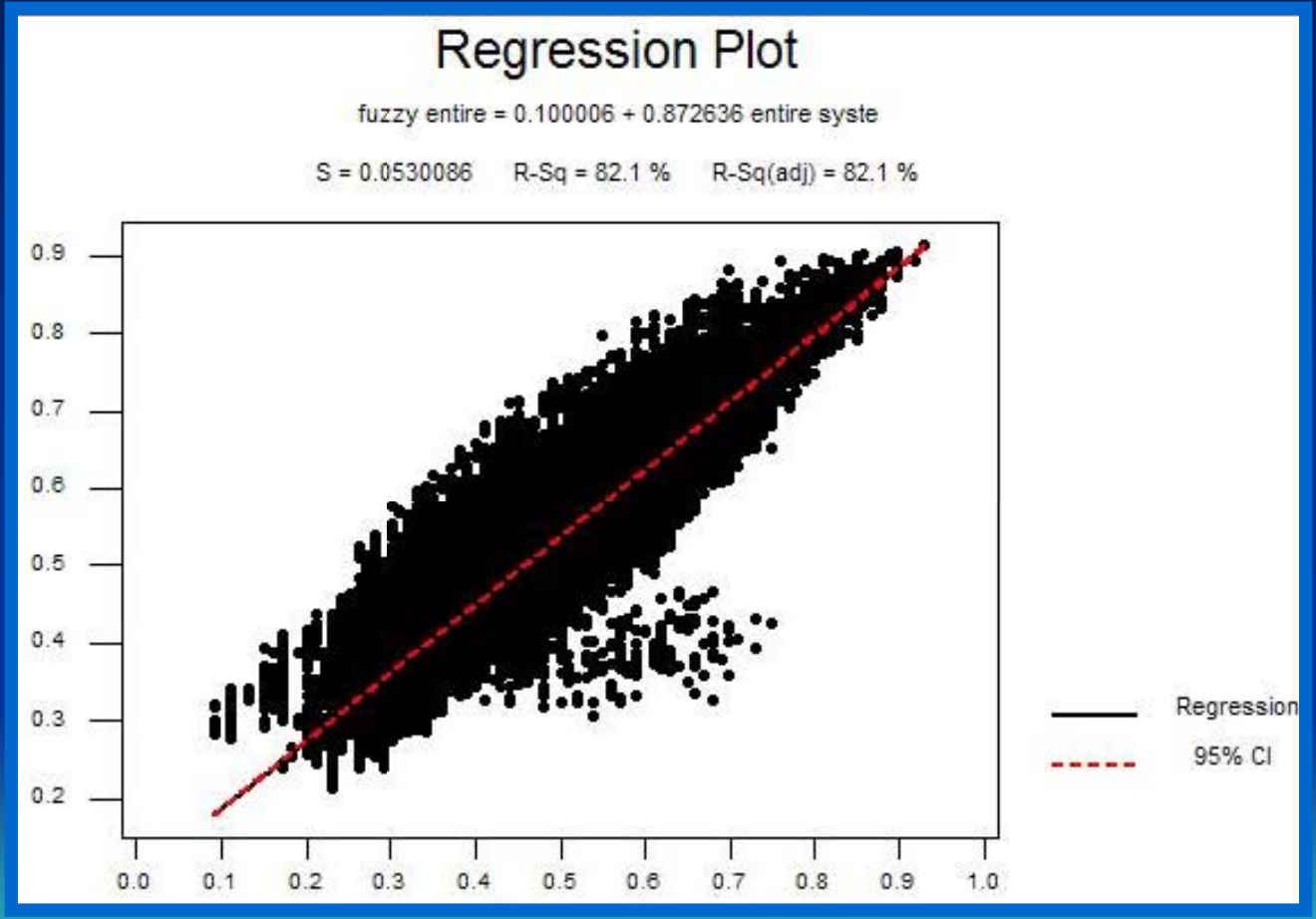
"the deliverable code correctly implements the original user requirements" (Gupta, 1990).

  - For the FEE Tool, one such test would be to see how well the system predicts the performance of new wells.

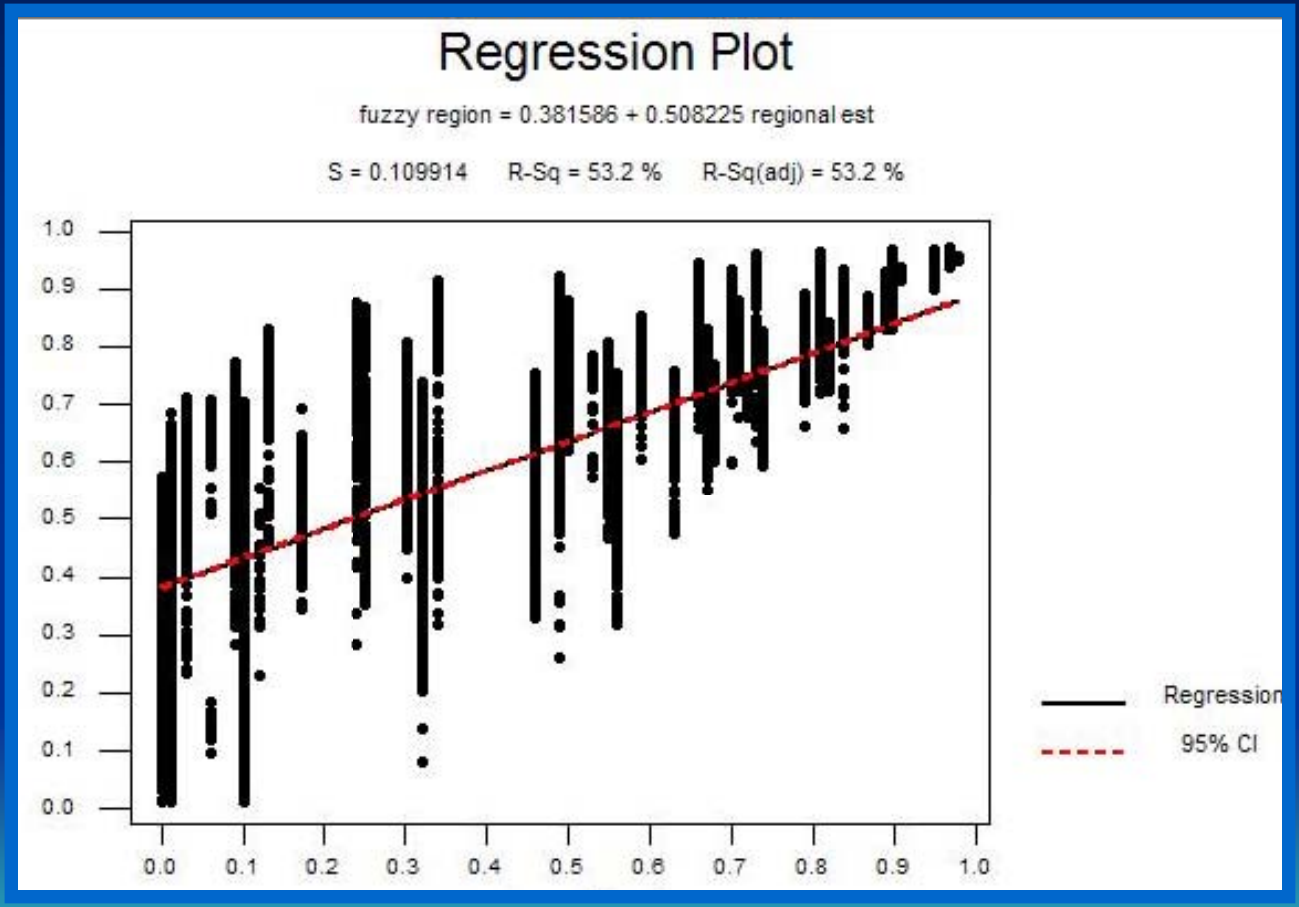
Validation Testing

- Each subroutine or sub-process was tested using synthetic data to make sure that all outputs and variable ranges were successfully calculated.
- Comparisons of fuzzy model to crisp model and conceptual model provides a measure of how well the code fits the “model”.

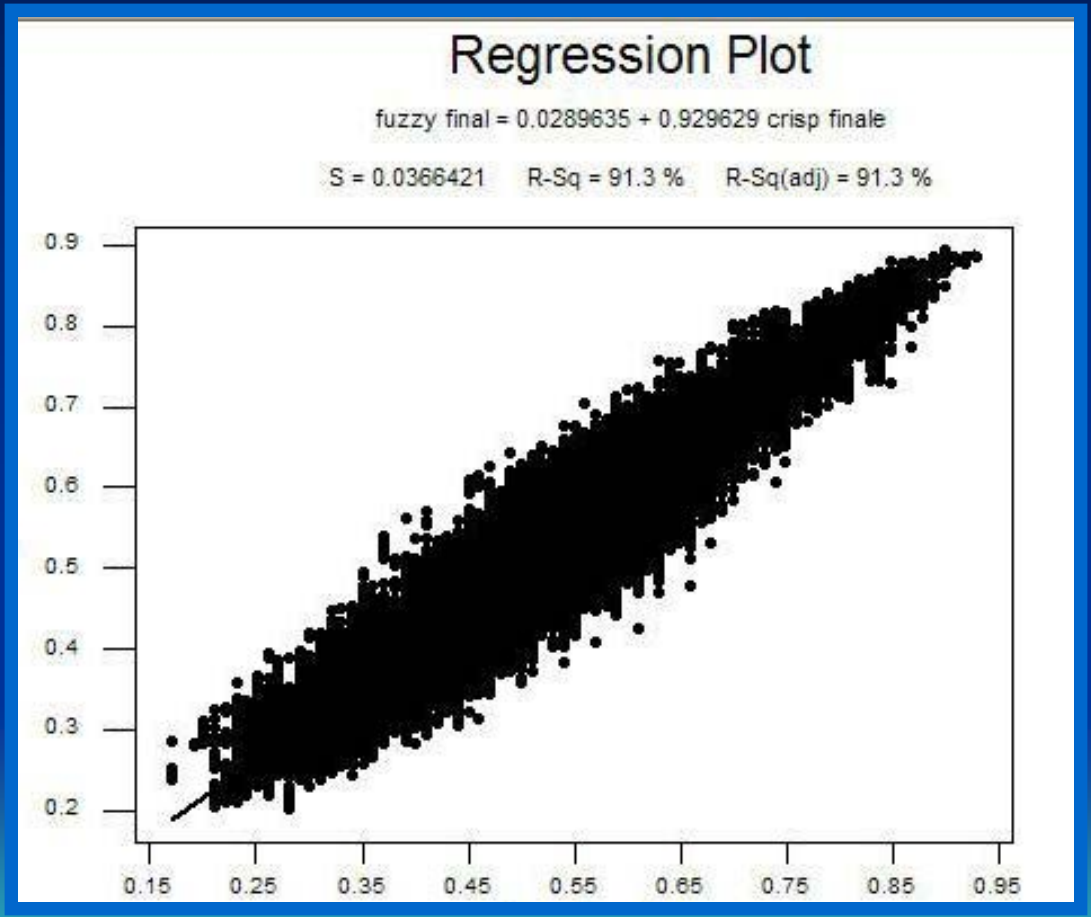
An Early Crisp vs. Fuzzy Plot



Regional Estimate Divided Out



Final Fuzzy and Crisp Correlation



Alpha and Beta Testing

- Alpha testing, or testing before release of software, was used to verify in-house that the major functions of the software worked in a stable manner.
- Beta Testing, or testing as a limited release, was used to give the software a trial by a small set of users.
  - Many interface change recommendations and a few bugs were found in this stage.

Verification Testing: Is It Effective?

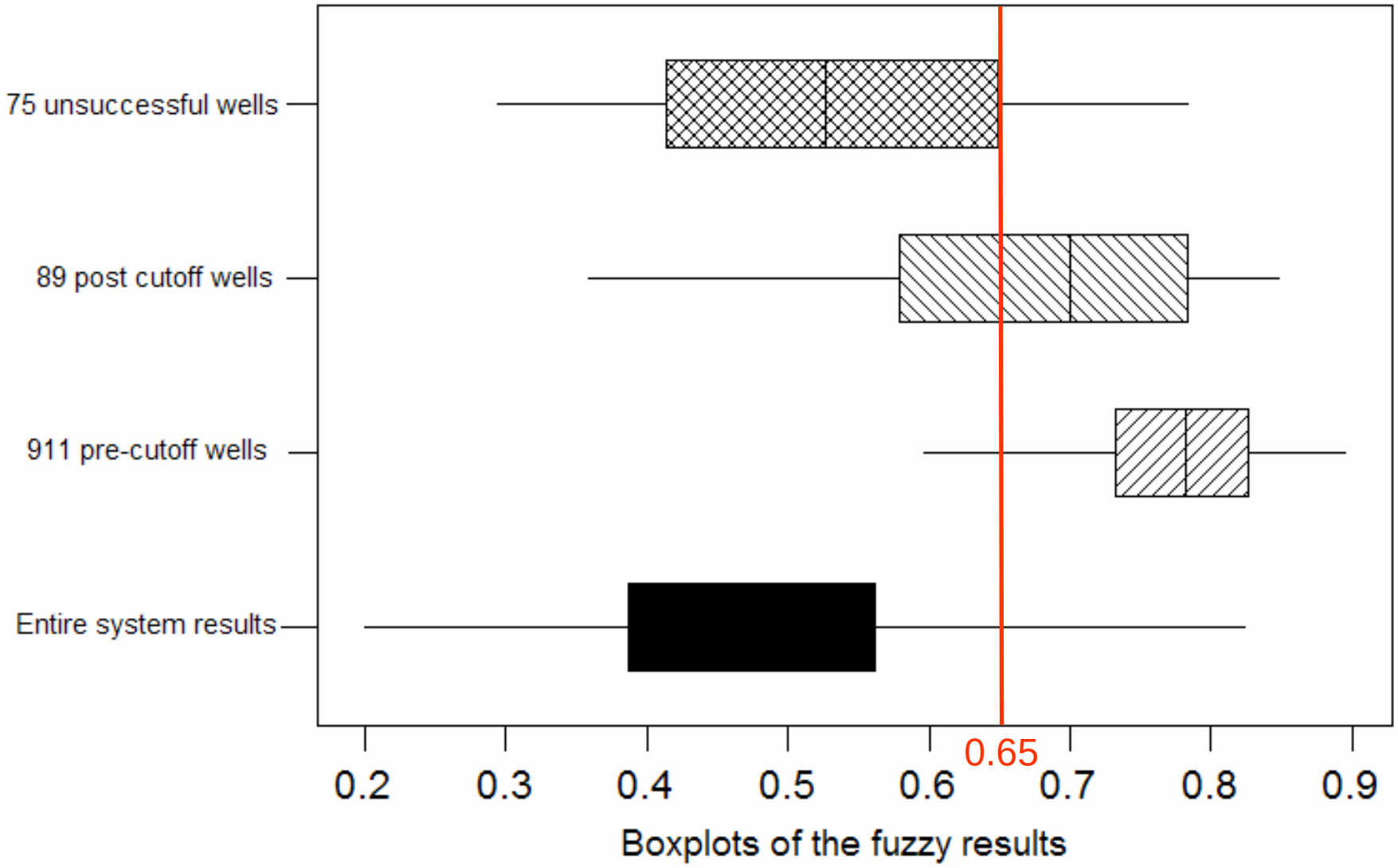
- How well does it predict Lower Brushy Canyon prospects?
  - How to best validate the expert system.
    - Test it using pre-generated answers
- The project databases were frozen at intervals, to allow new wells that were drilled to reach one year of continuous production, and be candidates for blind testing.

Project Results

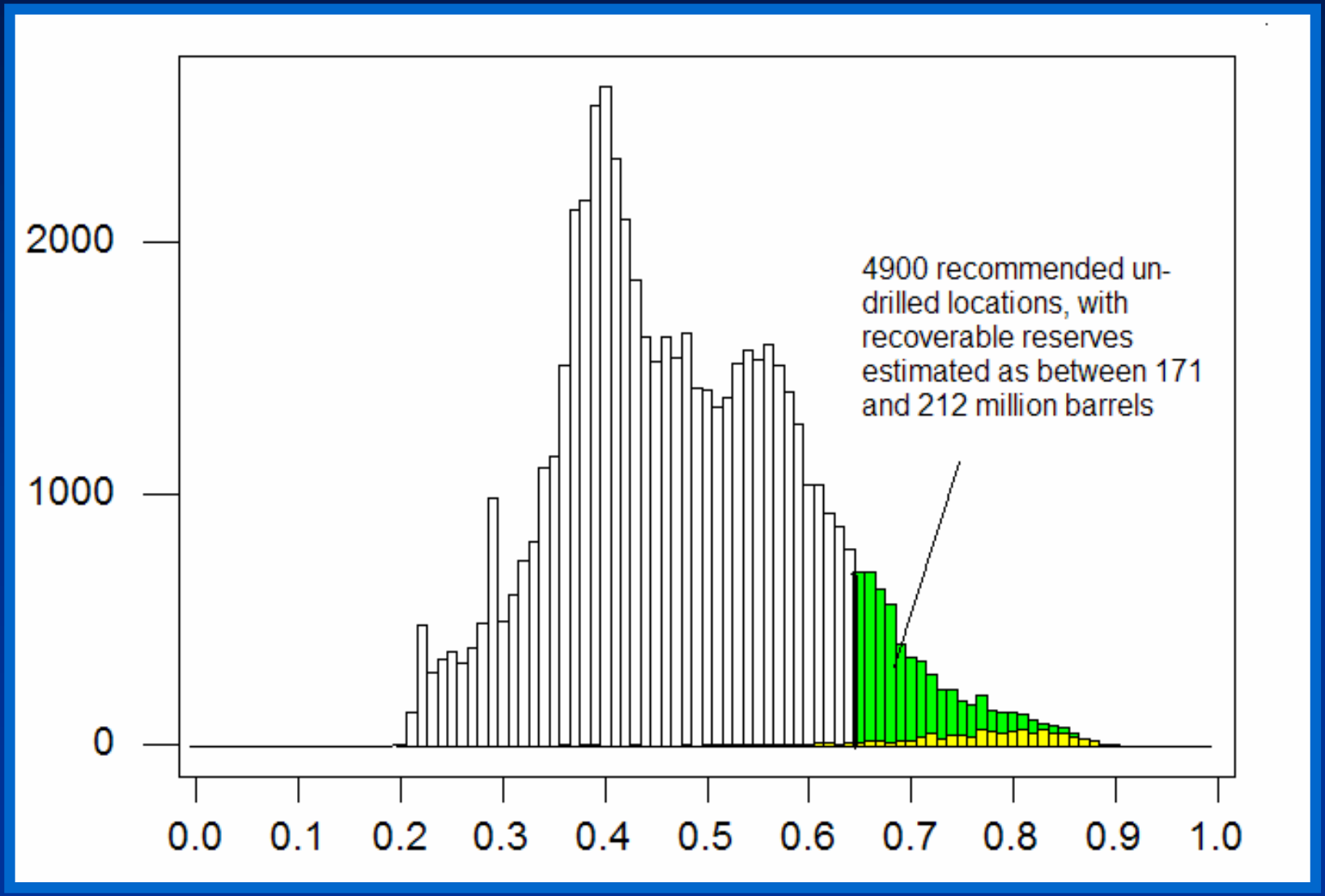
Is it Successful?

- We used statistics to help decide a numerical/linguistic value where the risk is optimally reduced.
- Boxplot statistics were one useful technique generated to help in this.
- Results were compared to actual results at real wells decided by human experts.

Delaware Comparative Statistics

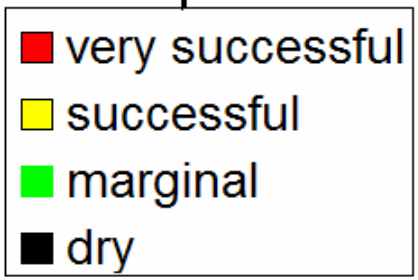


Delaware FEE Tool Quality Estimates for 60,478 Potential Drilling Sites

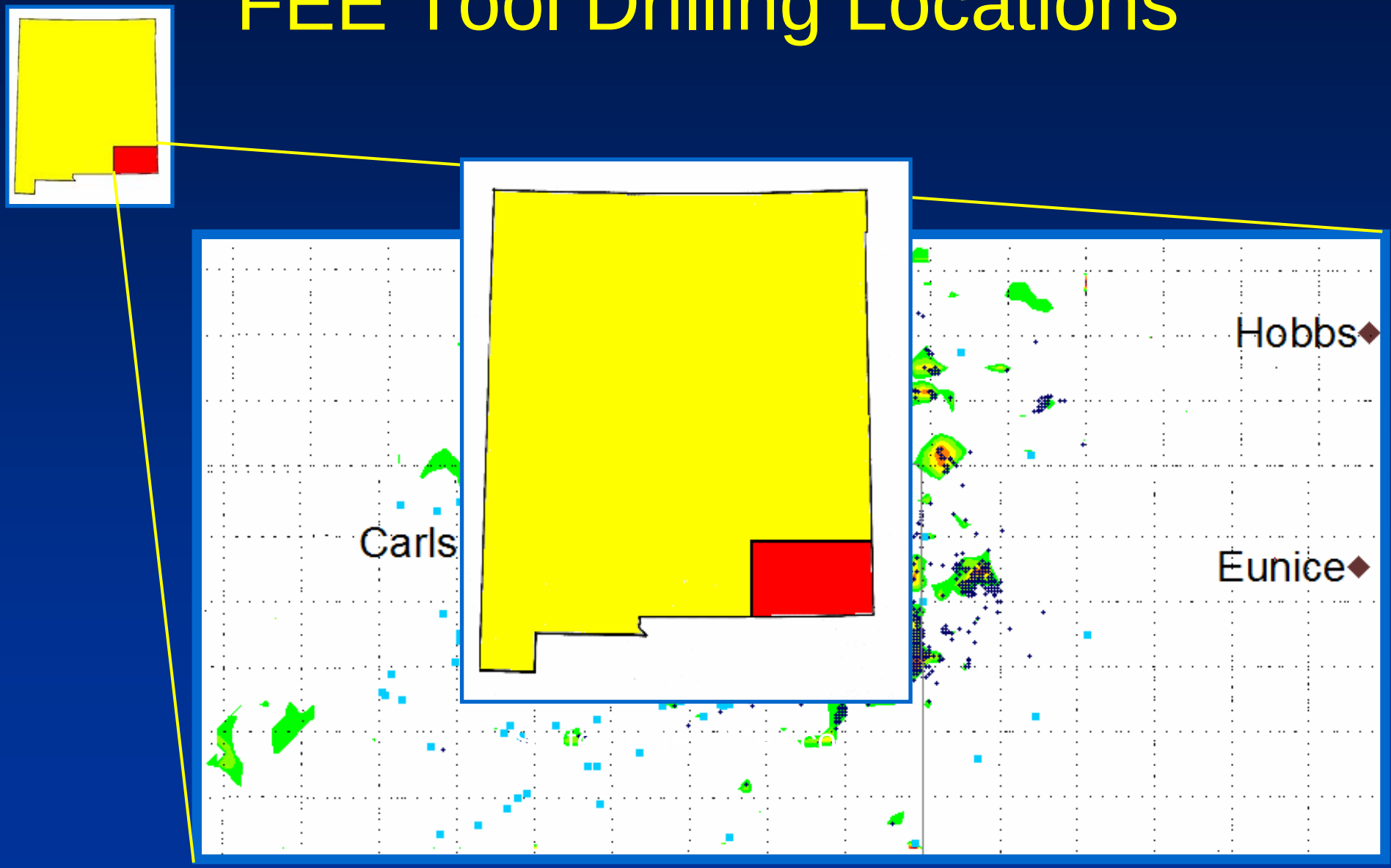


Wells drilled at locations recommended by the Delaware FEE Tool

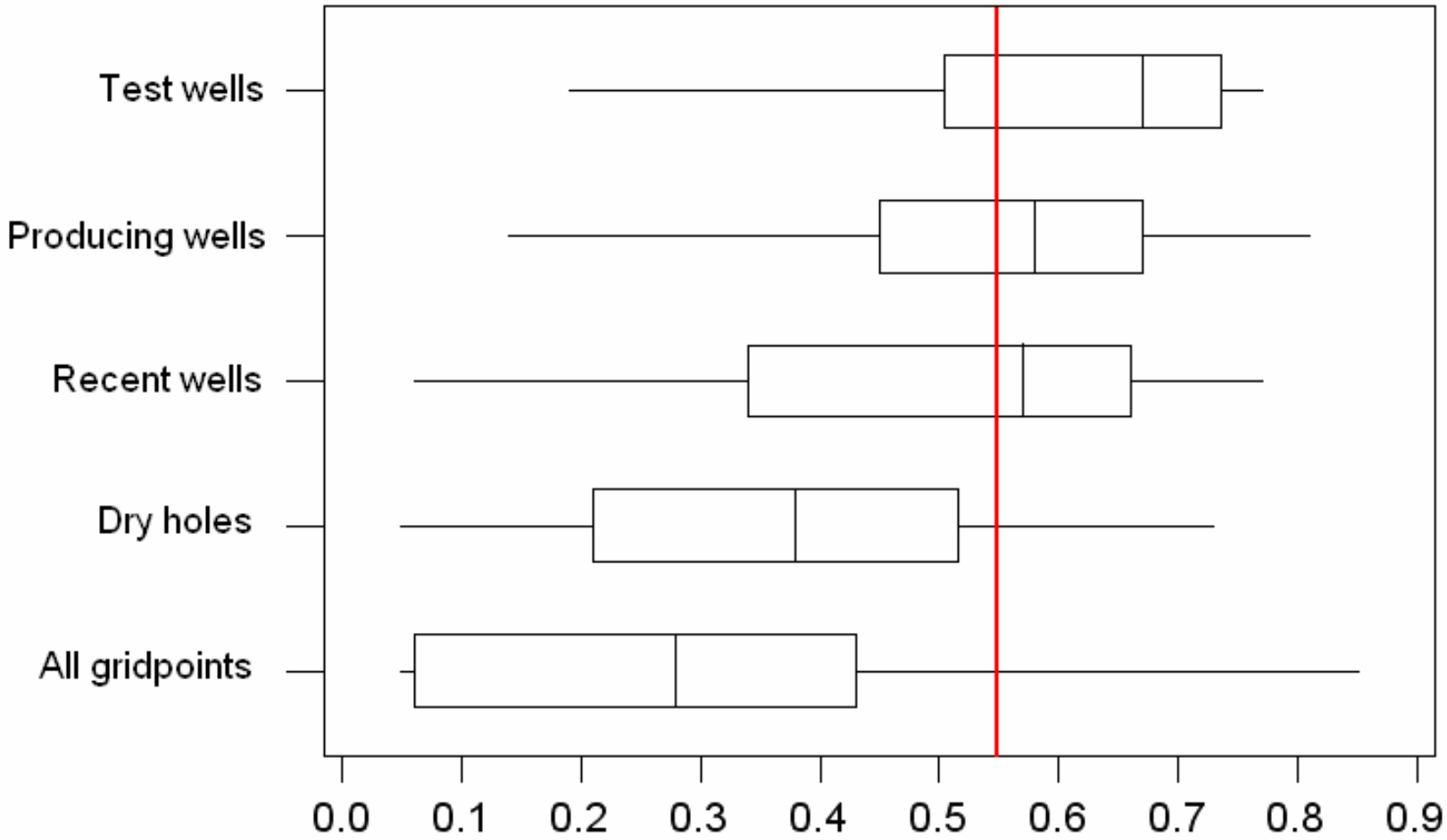
Wells drilled at non-recommended locations



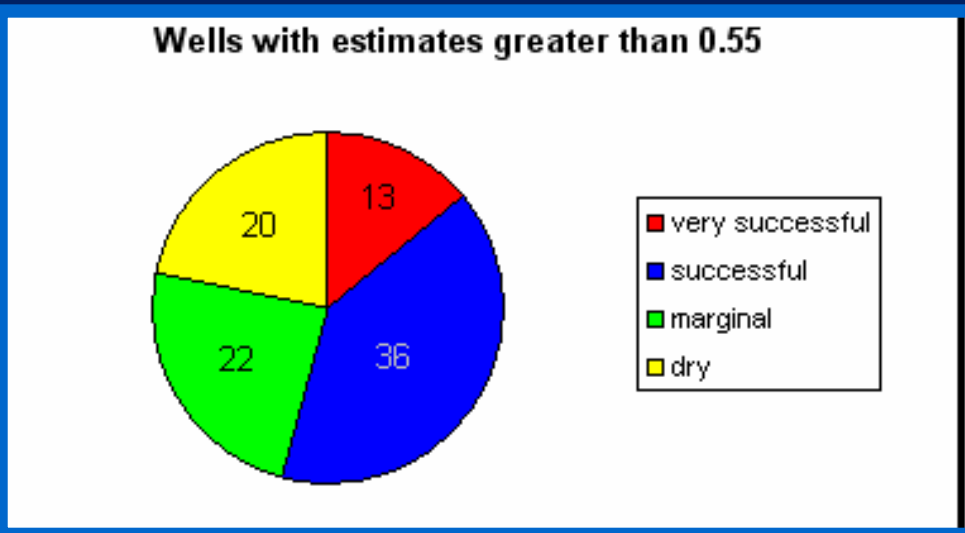
Recommended Delaware FEE Tool Drilling Locations

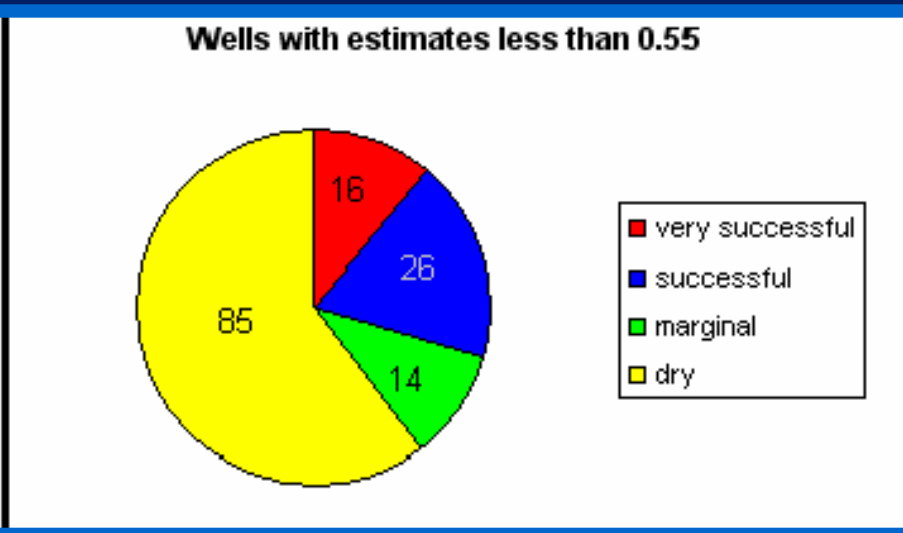


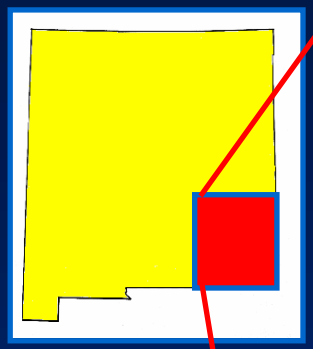
Devonian Box plot

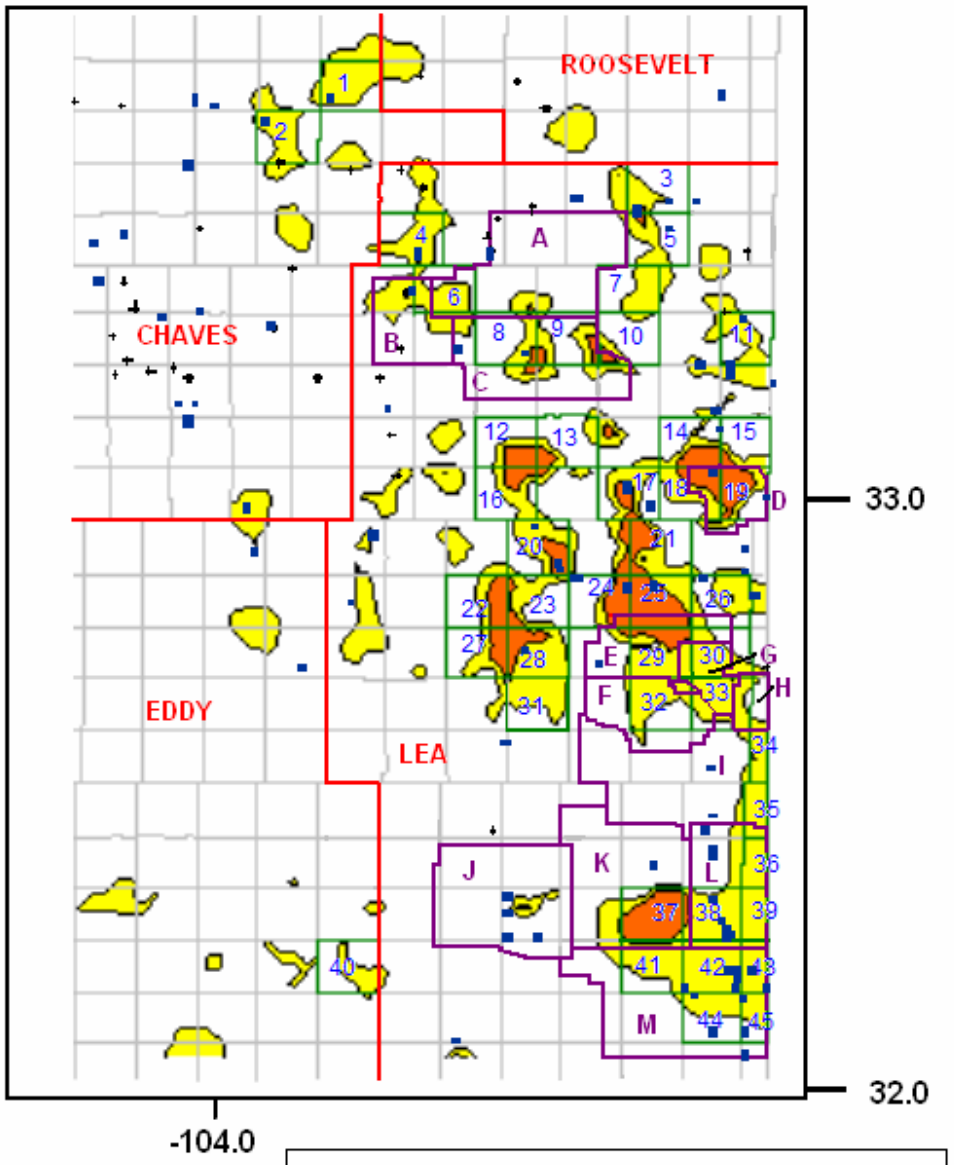


Devonian Pie Charts









Recommended region
Seismic Data
T-R
County line
FEE Tool estimate > 0.55
FEE Tool estimate > 0.70
Prod. well
Dry hole

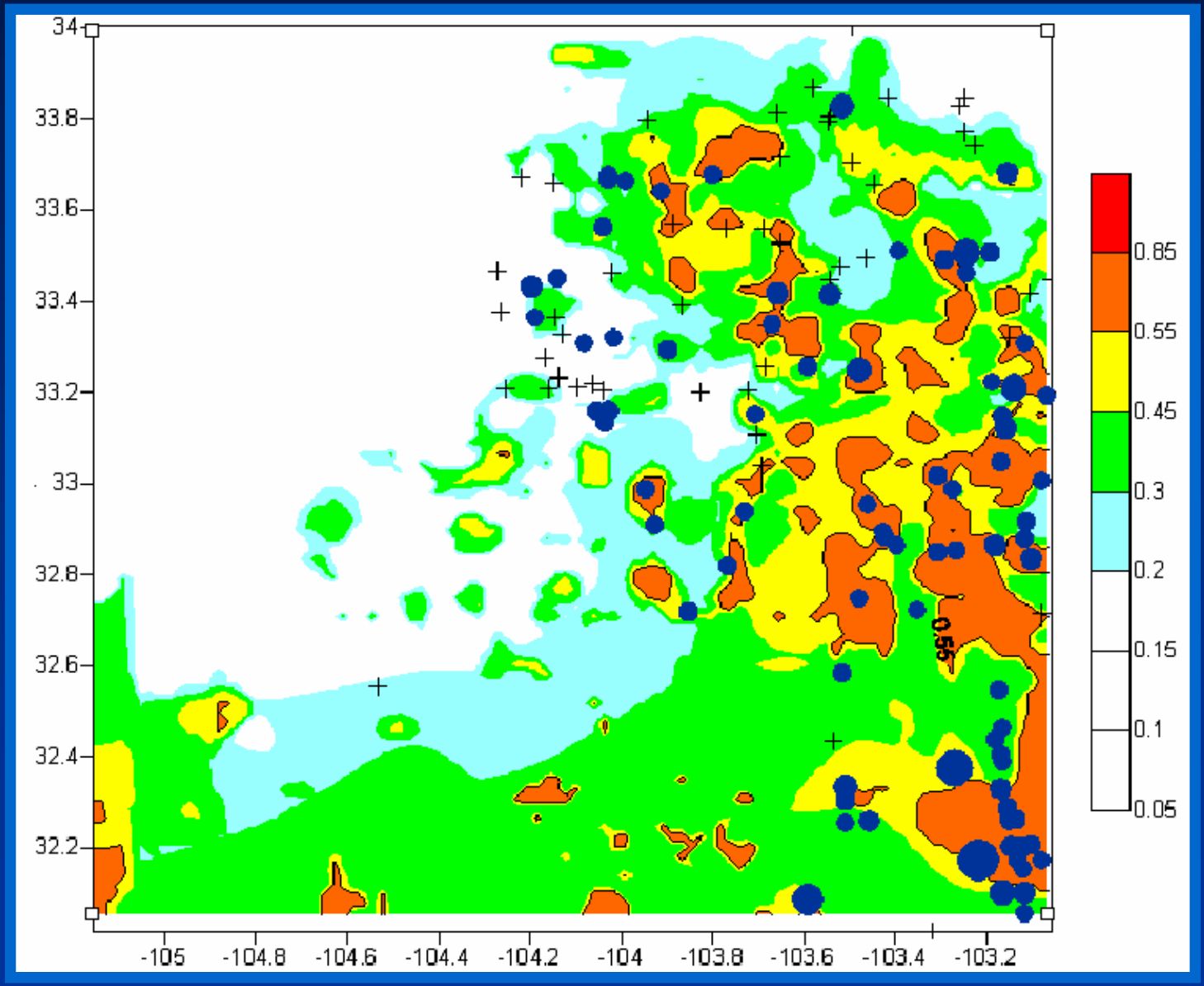
Locations

1: 7S 31E
2: 8S 30E
3: 9S 36E
4: 10S 32E
5: 10S 36E
6: 11S 33E
7: 11S 36E
8: 12S 34E
9: 12S 35E
10: 12S 36E
11: 12S 38E
12: 14S 34E
13: 14S 35E
14: 14S 37E
15: 14S 38E
16: 15S 34E
17: 15S 36E
18: 15S 37E
19: 15S 38E
20: 16S 35E
21: 16S 37E
22: 17S 34E
23: 17S 35E
24: 17S 36E
25: 17S 37E
26: 17S 38E
27: 18S 34E
28: 18S 35E
29: 18S 37E
30: 18S 38E
31: 19S 35E
32: 19S 37E
33: 19S 38E
34: 20S 39E
35: 21S 38E
36: 22S 38E
37: 23S 36E
38: 23S 37E
39: 23S 38E
40: 24S 31E
41: 24S 36E
42: 24S 37E
43: 24S 38E
44: 25S 37E
45: 25S 38E

Available Seismic Data
WesternGeco
Multiclient 3D surveys
www.westerngeco.com

A: NW Tatum Basin II
B: NW Tatum Basin IV
C: NW Tatum Basin I
D: East Lea
E: SE Lea VII
F: SE Lea V
G: S. Hobbs I and II
H: Tex NM III
I: SE Lea I and II
J: SW Lea I
K: SE Lea III
L: Tex NM I
M: SE Lea VI

Devonian Predictions



Application

FEE Tool – Recoverable Reserves

A Novel use for the FEE Tool

- With a global Quality prediction at each of 60,478 potential prospects, and
- With a well-defined cut-off quality of 0.65 for a most likely successful well.
- It becomes feasible to determine how many viable Lower Brushy Canyon prospects remain to be drilled in the New Mexico portion of the Delaware basin.
  - 4481 un-drilled prospects above that quality

Reserve Estimation Using the FEE Tool

- The missing variable is how much production can be expected at each of the prospects.
- We can use the quality rankings of the existing wells in the basin to determine an average production for a well that has an Expert System defined Quality prediction.

Approach

- Step 1: Collect data on first year average production for the 1000 wells producing out of the lower Brushy Canyon formation.
- Step 2: Determine the best ratio for converting first year average production (two approaches based on productive life of well).
- Step 3: Convert first year average production to total production using the ratio(s) found in step 2.

Approach

- Step 4: Using the FEE Tool estimates for the 1000 wells, find the mean value of total production at each FEE Tool estimate of 0.65 to 0.89 (the max). (0.65,0.66,0.67,…0.89).
- Step 5: Find the total number of gridpoints with an estimate of 0.65, 0.66, etc. These results are shown in the following table.

0.65	27174	33546	689
0.66	41135	50780	687
0.67	29968	36994	626
0.68	33615	41496	563
0.69	38031	46947	404
0.7	44131	54478	351
0.71	38150	47095	333
0.72	29846	36844	287
0.73	31451	38825	224
0.74	33910	41860	220
0.75	37333	46086	177
0.76	30233	37322	159
0.77	36049	44501	202
0.78	43521	53725	142
0.79	38677	47745	134
0.8	40393	49864	131
0.81	38331	47319	124
0.82	41774	51569	105
0.83	43727	53979	91
0.84	42239	52143	77
0.85	36576	45151	71
0.86	49654	61296	46
0.87	43395	53569	27
0.88	54817	67669	19
0.89	53445	65976	8

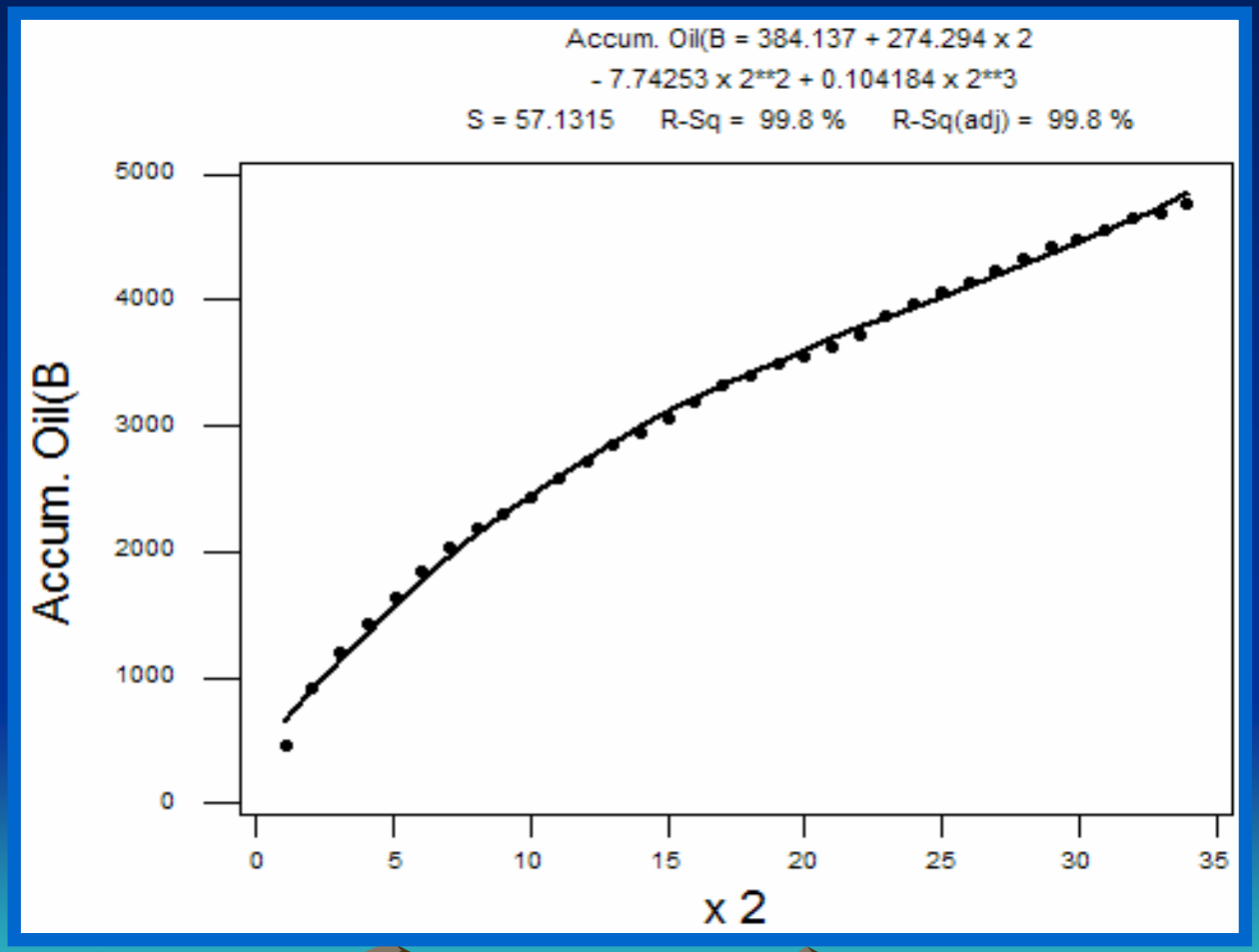
Approach

- Step 6:The reserves are computed by the following formula:

$$\text{Reserves} = \Sigma T_i G_i - TP$$

  - Total production at the i^{th} estimate level $= T_i$
  - Number of gridpoints at the i^{th} estimate level $= G_i$
  - Total production at 1000 wells (step 3) = TP

Cumulative Prod. vs. Number of Months



Preliminary Results

- Using the 100 bbl/month end of productive life, the reserve value computed using this method is 171,613,995 bbls.
- Using the 0 bbl/month end of productive life, the reserve value computed is 211,851,015 bbls.
- The actual remaining recoverable reserves, estimated using the Expert System, will fall between these two numbers.

Summary

- Remaining recoverable reserves for the lower Brushy Canyon play was undertaken using data predicted by the "machine" expert.
- Between 170 and 212 Million Barrels of recoverable oil remain in the ground in 4481 un-drilled prospects.
- Of the 4481 prospects we expect:
  - 1.91 % or 86 dry holes
  - 22.02 % or 987 marginal wells
  - 76.07 % or 3408 successful or very successful wells

Summary

- We predict the 987 marginal wells will produce between 7.2 and 8.9 MBBls of oil total.
- The production at the 3408 successful or very successful wells is therefore predicted at between 48,248 and 59,560 barrels average per well.

Conclusions

Conclusions

- A web-based Fuzzy Expert Exploration Tool has been successfully developed using Fuzzy Logic and Java technology.
- Two types of rules are applied in up to four categories:
  - Regional, Trap, Structure and Formation Assessment.
  - Each assessments assigns a numerical score based on the answers to expert questions.
- Results are combined to form an overall risk assessment associated with the prospect.

New Technology

- The project created the first fuzzy expert systems used in oil exploration:
  - Both systems utilize state of the art software and webware.
- The Expert Systems warehouse hard-learned expert knowledge in an easily queried format.
- Make accessible via the internet a large variety of useful information and tools for Explorationist's.

Future Work

Customizable Fuzzy Expert System

Project funded by Department of Energy

- Tools to allow the development of Fuzzy Expert Systems by Engineers and Scientists.

Questions

?