USGS
science for a changing world

Quick-Start Guide for Version 3.0 of EMINERS—Economic Mineral Resource Simulator

By Walter J. Bawiec and Gregory T. Spanski

A supplement to USGS Open-File Report 2004–1344, Version 3.0 of EMINERS—Economic Mineral Resource Simulator, by J.S. Duval

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment—visit
http://www.usgs.gov or call 1–888–ASK–USGS

For an overview of USGS information products, including maps, imagery, and publications,
visit *http://www.usgs.gov/pubprod*

To order this and other USGS information products, visit *http://store.usgs.gov*

Contents

Table

Quick-Start Guide for Version 3.0 of EMINERS—Economic Mineral Resource Simulator

By Walter J. Bawiec and Gregory T. Spanski

Introduction

Quantitative mineral resource assessment, as developed by the U.S. Geological Survey (USGS), consists of three parts: (1) development of grade and tonnage mineral deposit models; (2) delineation of tracts permissive for each deposit type; and (3) probabilistic estimation of the numbers of undiscovered deposits for each deposit type (Singer and Menzie, 2010). The estimate of the number of undiscovered deposits at different levels of probability is the input to the EMINERS (Economic Mineral Resource Simulator) program.

EMINERS uses a Monte Carlo statistical process to combine probabilistic estimates of undiscovered mineral deposits with models of mineral deposit grade and tonnage to estimate mineral resources. It is based upon a simulation program developed by Root and others (1992), who discussed many of the methods and algorithms of the program. Various versions of the original program (called "MARK3" and developed by David H. Root, William A. Scott, and Lawrence J. Drew of the USGS) have been published (Root, Scott, and Selner, 1996; Duval, 2000, 2012).

The current version (3.0) of the EMINERS program is available as USGS Open-File Report 2004–1344 (Duval, 2012). Changes from version 2.0 include updating 87 grade and tonnage models, designing new templates to produce graphs showing cumulative distribution and summary tables, and disabling economic filters. The economic filters were disabled because embedded data for costs of labor and materials, mining techniques, and beneficiation methods are out of date. However, the cost algorithms used in the disabled economic filters are still in the program and available for reference for mining methods and milling techniques included in Camm (1991).

EMINERS is written in C++ and depends upon the Microsoft Visual C++ 6.0 programming environment. The code depends heavily on the use of Microsoft Foundation Classes (MFC) for implementation of the Windows interface. The program works only on Microsoft Windows XP or newer personal computers. It does not work on Macintosh computers.

This report demonstrates how to execute EMINERS software using default settings and existing deposit models. Many options are available when setting up the simulation. Information and explanations addressing these optional parameters can be found in the EMINERS Help files. Help files are available during execution of EMINERS by selecting **EMINERS Help** from the pull-down menu under **Help** on the EMINERS menu bar.

There are four sections in this report. Part I describes the installation, setup, and application of the EMINERS program, and Part II illustrates how to interpret the text file that is produced. Part III describes the creation of tables and graphs by use of the provided Excel templates. Part IV summarizes grade and tonnage models used in version 3.0 of EMINERS.

Acknowledgments

The authors thank USGS colleagues Michael L. Zientek and Mark J. Mihalasky for their insightful technical reviews of this manuscript and Peter N. Schweitzer for his help in understanding the code of this program.

Part I. Installation, Setup, and Application

Installation and Setup

The EMINERS program can be used only on a Windows-based platform.

1. Copy the file **EMINERS.zip** to a folder on your computer where the EMINERS program will reside.

2. Unzip the **EMINERS.zip** file.

3. If the unzip process does not create a subfolder under EMINERS called **EMINERS Output**, create that folder.

EMINERS Application

To execute EMINERS, double click on the file **EMINERS.EXE** to launch the application. When this program is executed for the first time or when the locations of the EMINERS program and files are unfamiliar (for example, they are running from a compact disc), a window stating, **"Unable to open EMINERS initialization file!"** will appear.

1. Click **OK**.

2. The window **"Please locate the EMINERS configuration file (ModlData.txt)"** appears. Navigate to the disk drive and then to the folder that contains the EMINERS configuration file (**ModlData.txt**). This step is necessary because the user may have copied these program files to various disk drives and file locations.
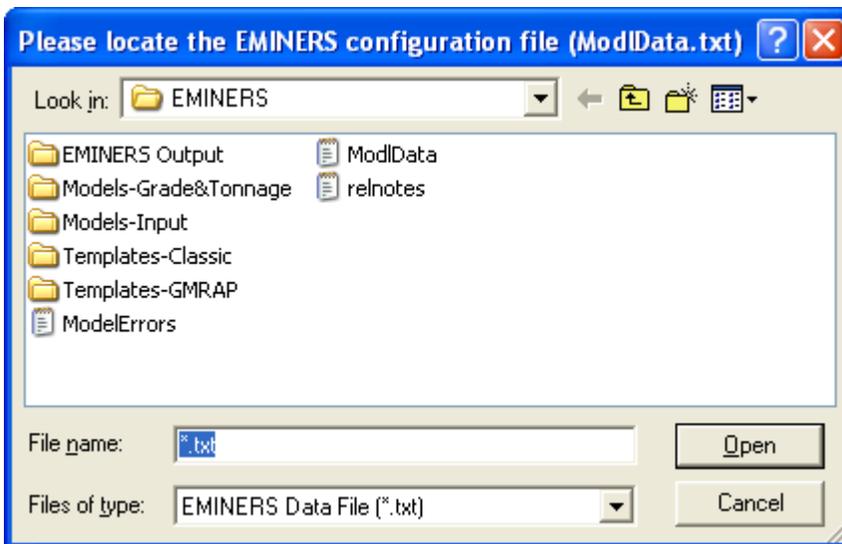
3. Select **ModlData.txt** and click **Open** to open the file. The window **"EMINERS - Eminer1"** opens. This window may be enlarged by dragging its corners. The window provides information on how to start using the program.
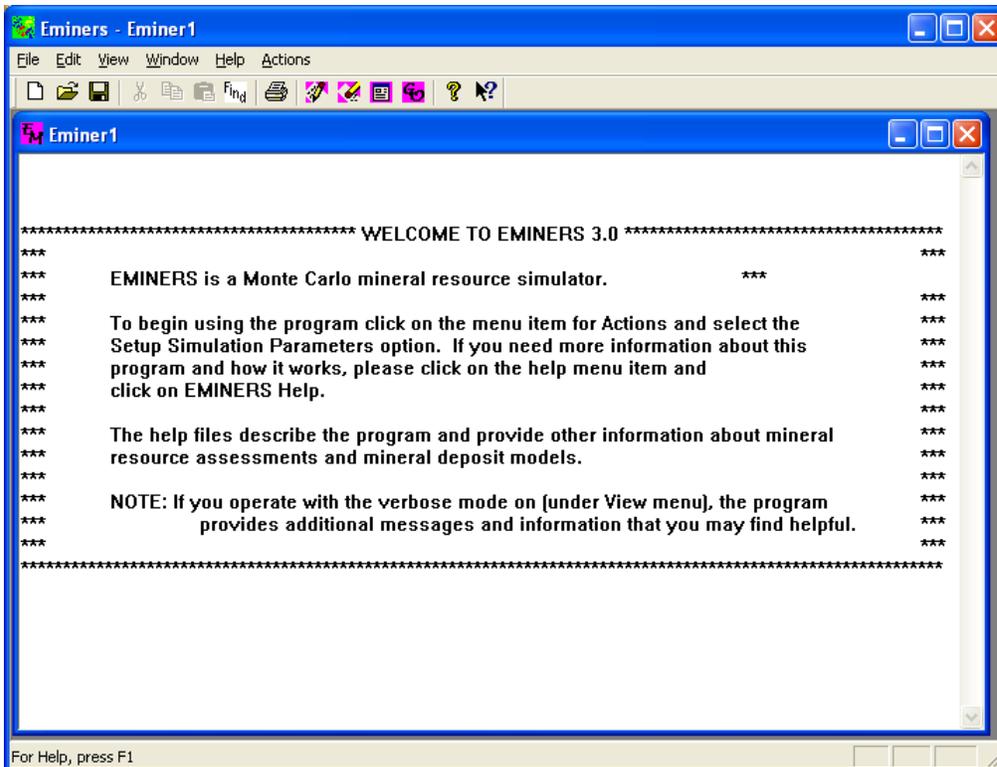
4. Under **Actions** in the menu bar in the window "Eminers – Eminers1," select the option **Setup Simulation Parameters** from the pull-down menu.

5. The window **"Initial Data for Mark3"** opens:
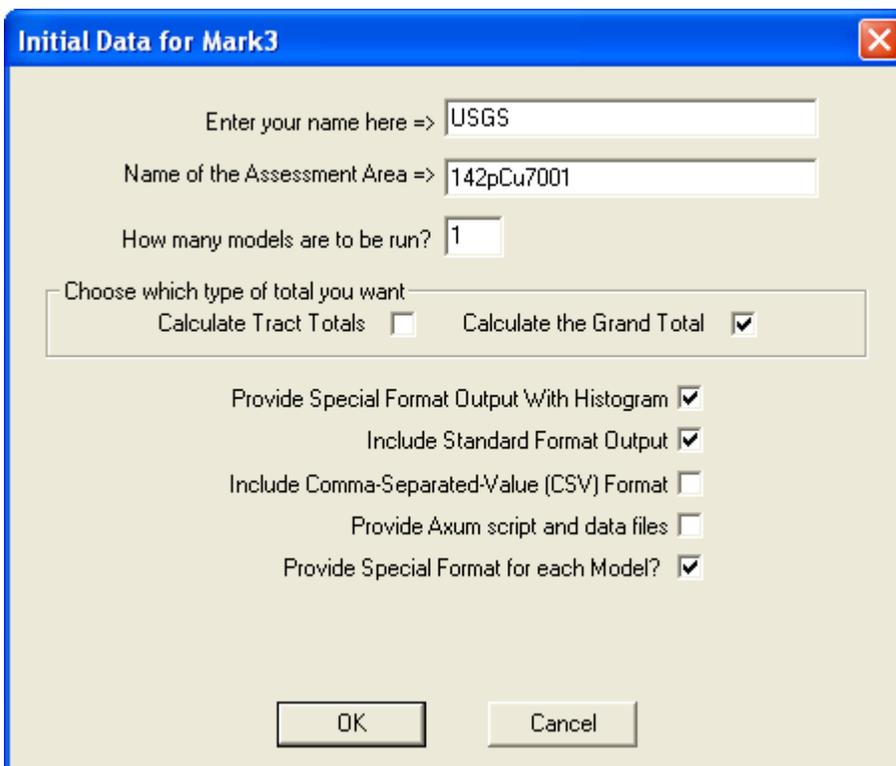
a. Enter your name in **Enter your name here =>** box. This name will appear in the EMINERS output table.

b. Enter the name of the assessment tract in **Name of the Assessment Area=>** box. The name may contain as many as 50 alphanumeric characters, although fewer are recommended because this information is used in output file names. Blank spaces, commas, or other special characters should NOT be used in assessment area names because their use can cause errors when the output files are created.

c. Enter a numeric value in **How many models are to be run?** box. If you are running EMINERS for a single deposit model, enter the number 1 or strike the TAB key to move to the next field. The output will produce results that can be incorporated into the Excel templates for graphs and tables. However, if more than one model is calculated per tract, or more than one tract is calculated and aggregated, while the EMINERS results for metal endowment are correct (assuming complete dependence), they are not in the proper format to be displayed in the Excel templates to create graphs and tables.

d. Choose which type of total you want. The default setting is **Calculate the Grand Total**. This will provide the proper format for the Excel templates.

e. Select the types of formats you want produced. Default settings are **Include Standard Format Output** and **Provide Special Format for each Model**. Information related to each of these output formats can be found by doing the following steps[1]:

   1. Click on **Help** in the menu bar.
   2. Select **EMINERS Help**.
   3. Click on the **Find** TAB.
   4. Search for the word "format."
   5. Click on the format of interest in the topics list.
   6. Click on **Display**.

f. Check the box next to **Provide Special Format Output With Histogram**. Including this option creates a CSV file that can be used with the Microsoft Excel templates to produce the tables and graphs for reports and presentations described in "Part III. Creation of Tables and Graphs by Use of Excel Templates."

g. Click **OK**.

6. The window **"Select the first deposit model."** opens:

a. Select the model you wish to use from this pull-down list.

---

[1]To use the Help files provided with EMINERS, users of Windows Vista and beyond (including Windows 7, Windows Server 2008, Windows Server 2008 R2, and any version of Windows 8) must obtain and install the Windows Help program (WinHlp32.exe) appropriate to their operating systems. Microsoft support describes the reasons and necessary steps here: *http://suppport.microsoft.com/kb/917607* (accessed March 23, 2012).
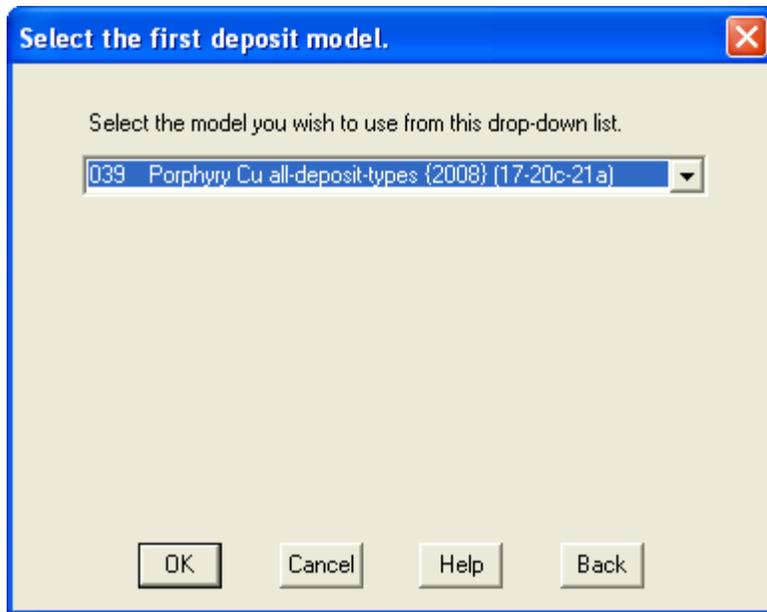
    b.   Click **OK**.

7. The window **"Select the Type of Probability Function, Code Name, Probability Gro…"** opens:
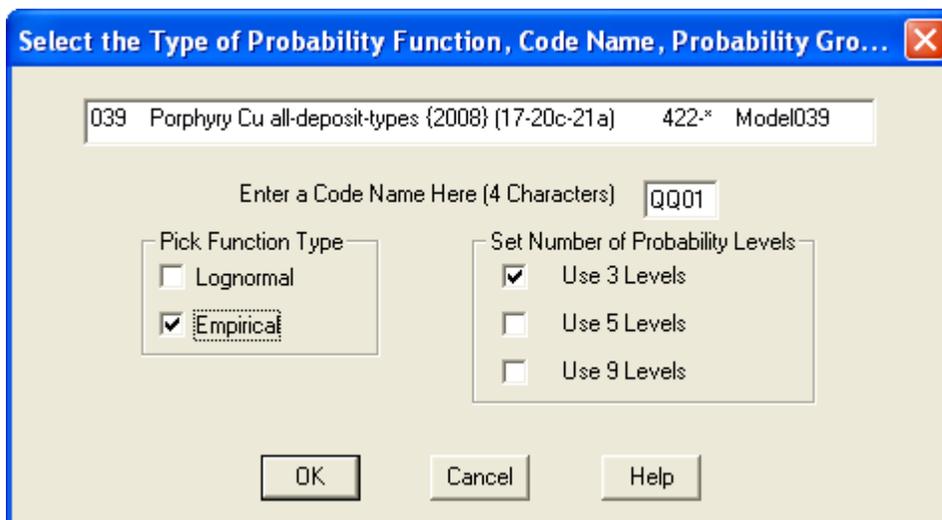
    a.   **Enter a Code Name Here** is a dummy variable field that can be used for tracking separate runs; it appears in the EMINERS output and does not need to be replaced.

    b.   **Pick Function Type**; the default setting is **Empirical**. Use **EMINERS Help**, **Find** for more information.

    c.   Check the appropriate value for **Set Number of Probability Levels**; for USGS studies, this number is determined by the assessment team doing the quantitative assessment.

    d.   Click **OK**.

8. The window **"Estimate Number of Deposits"** opens:
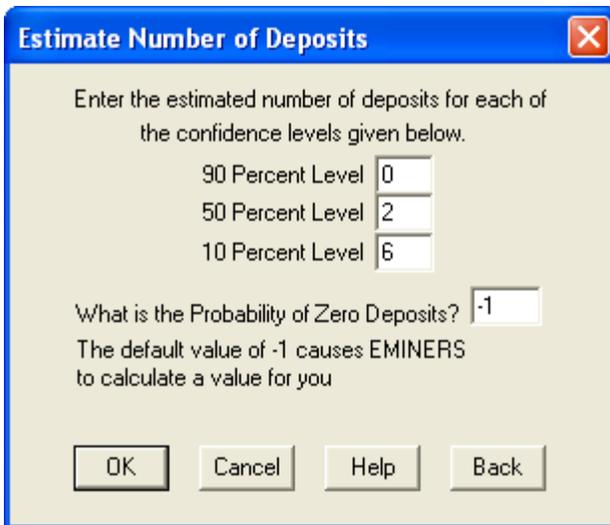
a. Enter an integer value for each level; you can use the TAB key to move through all data entry fields. Click on the **Help** button for more information.

b. In most cases, accept the default value of –1 in the **What is the Probability of Zero Deposits?** box. The value of –1 allows the program to calculate the default probability of zero deposits. This calculation is dependent upon the input distribution and results in a nonzero value for the probability of zero deposits. If you are unsure about this option, enter a value of –1 and allow the program to calculate the probability of zero deposits.

c. Click **OK**.

9. The window **"Open"** appears. At this point, the location of the grade and tonnage input files in the **Models-Input** folder must be identified.
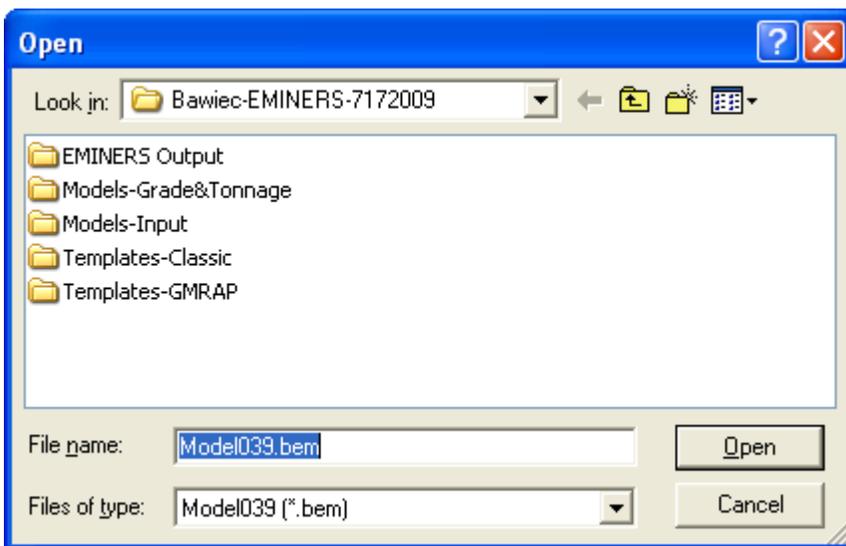
a. Double click on the **Models-Input** folder.

b. Click **Open**.

10. The window **"Locate Directory for CSV files and CLICK OK."** opens:

Locate Directory for CSV files and CLICK OK.

Look in: EMINERS Output

File name: x.csv

Files of type: Axum CSV File (x.csv)

Open

Cancel
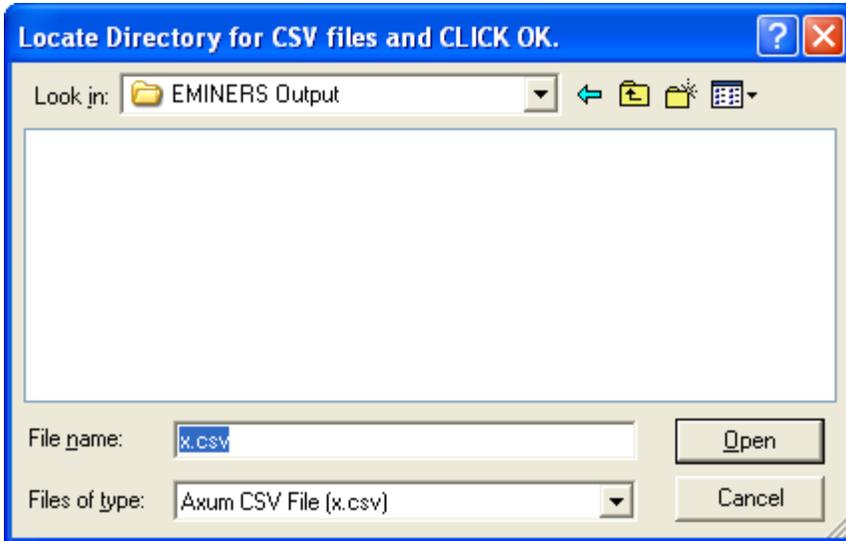
a. Navigate to the folder where the output files are to be saved; for example, the folder **EMINERS Output** that was created during the installation and setup. This folder can be used to store graphical output and tables.

b. **Do not change the file name or file type in this box.** The default file name 'x' is automatically replaced by a new name generated by the software composed of the assessment area name, a model number, and a three-digit number with the form "AAAA_Modelnnn_Excell000.csv" where AAAA is the name chosen for the assessment area, and "nnn" will be the number of the deposit model used by EMINERS (for example, 039).

c. Click **OPEN** (which actually means "save") to save the .csv file.

11. EMINERS executes, and the results are displayed in the window **"Eminer1."**

EMINERS simulation results
(expressed in metric tons)

Requested by: USGS
Assessment area: 142pCu7001
Data requested: Tuesday, July 21, 2009 at 01:48:06 pm

```
***********************************************************************
***         1         — Processing Model Number  39 —      Empirical
        The code name assigned to this model calculation is QQ01

        Probability of Zero Deposits = -1.0000

        039 - Porphyry Cu all-deposit-types {2008} (17-20c-21a)

        90 pct    50 pct    10 pct    Type
           0         2         6      Empirical

        Random Number Seed = 1248198486

                 Sorted simulation results for Cu
                      Order of occurrence
        Unconditional                        Conditional

Prob     Index     Amt.              Prob     Index     Amt.
                   (metric tons)                       (metric tons)

1.0000     0       0.000000e+000     1.0000    1003     6.137457e+003
0.9500    250      0.000000e+000     0.9474    1213     2.642930e+005
0.9000    500      0.000000e+000     0.8949    1423     5.965616e+005
0.8500    750      0.000000e+000     0.8423    1633     1.001383e+006
0.8000   1000      0.000000e+000     0.7898    1843     1.472215e+006
0.7499   1250      2.999777e+005     0.7372    2053     2.065332e+006
0.6999   1500      7.368798e+005     0.6847    2263     2.690487e+006
0.6499   1750      1.255405e+006     0.6321    2473     3.455813e+006
0.5999   2000      1.886532e+006     0.5796    2683     4.258361e+006
0.5499   2250      2.642036e+006     0.5270    2893     5.253251e+006
0.4999   2500      3.516692e+006     0.4745    3103     6.196372e+006
```

For Help, press F1

This output shows the initial data entered into EMINERS and the results of the Monte Carlo simulation, which include calculated probabilistic ranges of estimated values for commodity endowments and deposit tonnage with estimated mean values for each range, and an estimate of the mean number of undiscovered deposits. An explanation of how to read and understand this file can be found in next section of this report.

12. Under the **File** pull-down menu, click **Save** in the menu bar to open the window **"Save As."**

    a.   In the **Save In**: message box, browse to the **EMINERS Output** folder created earlier, and change the name of the file from "Eminer1.emr" to a unique name. We suggest using the assessment area tract name. The results of the simulation will be stored in a text file with the .emr extension.
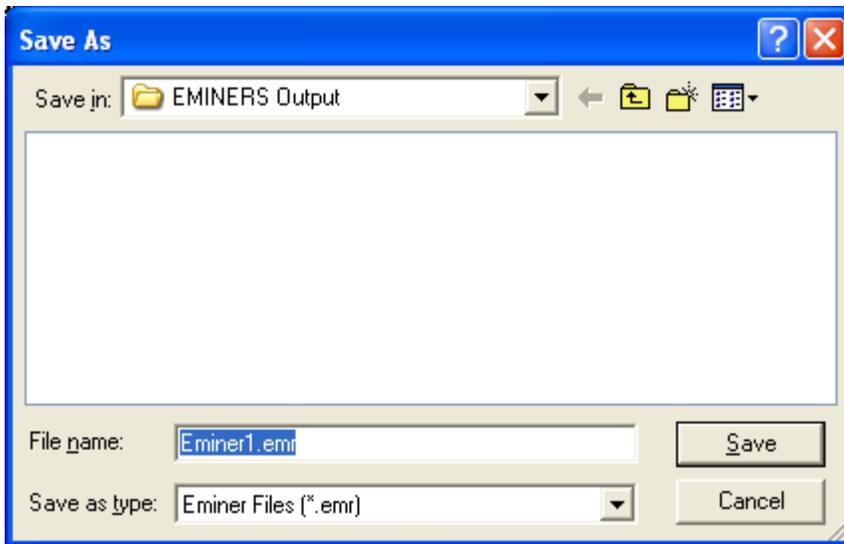
    b. Click **Save**.

Files saved to the **EMINERS Output** folder include those listed in the image below:
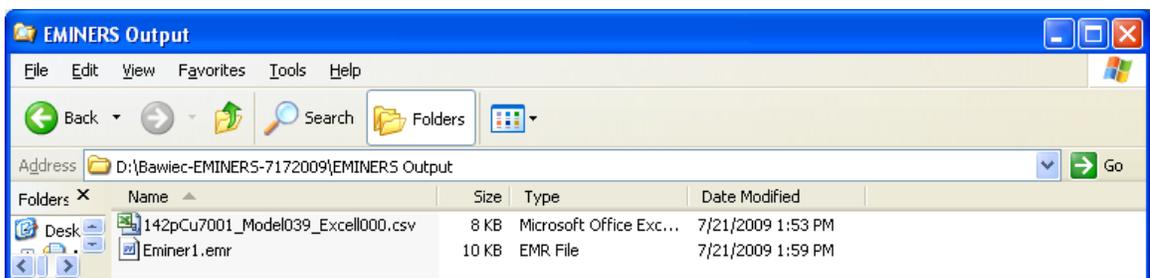
      You can print the results of this window by selecting **File>Print**. If you have Adobe Acrobat installed, you can create a PDF file of this output by selecting **Adobe PDF** as your printer.

      If you want to view these results again after closing the **"Eminer1"** window, navigate to the folder containing the **.emr** file saved from this simulation and use **Open** to open the **.emr** file using either Wordpad or Microsoft Word.

Part II. Understanding an EMINERS Output File

      This chapter is designed to familiarize the user with the content of the EMINERS (**.emr**) output file. A single set of deposit estimates and a single type of deposit model are used. The resulting output report contains (1) a series of statistical summaries for each commodity and deposit tonnage included in the deposit model and (2) the expected mean number of deposits.

      For illustrative purposes, only the first page of what would be a multipage output report is shown. The report contains two basic types of output, which are outlined in red in the following xample: "Input Parameters Box" and "Simulation Results Box." Each report contains a single set of input parameters, which appear in the Input Parameters Box, followed by from two to eight sets of simulation results, which appear in the Simulation Results Box. There will be one set of simulation results for each commodity, and one for deposit tonnage. An explanation of the EMINERS results can also be found in the EMINERS program Help file (Help/EMINERS Help/Discussion of the EMINERS program/Table of Contents/How to…./Interpret the Results).

Input Parameters Box—contains a tabulation of input values that are provided by the user at the program interface at the start of a run. The numbers given below correspond to the red numerals enclosed in circles on the sample report.

1. Name of the person supplying the input data and performing the run.

2. Unique name for the assessment area.

3. Date and time stamp indicating when the EMINERS run was performed.

4. Number (1, in this example) indicates the number of models in the run, if multiple models are being run. Runs utilizing the supplied templates to create graphs and tables are limited to the use of only one model; this value will always remain 1.

5. Number (39, in this example) assigned to the deposit model in the EMINERS deposit model list (see table 1).

6. Identifies the method (empirical versus lognormal) used to approximate grade and tonnage values in the deposit models. See the EMINERS Help file for more detail on the empirical method.

7. A four-character code that is available to the user to further identify a tract being run. The default value QQ01 appears unless the user deletes or replaces the value.

8. The value for the probability of zero deposits can be equal to –1 or 0 or can be in the range of 0 to 1.0.

9. Deposit model number (039, in this example) and model name and year (Porphyry Cu all-deposit-types 2008, in this example).

10. Lists the undiscovered deposit estimate set (0, 2, 6, in this example) at the 90%, 50%, and 10% probability levels and the grade and tonnage model data approximation method (empirical or lognormal) used in a run.

11. Random number generated by the program that was used in the Monte Carlo simulation of EMINERS.

Simulation Results Box—contains summary statistical information that characterizes the 4,999-member simulation population that EMINERS generates during a run. An output file contains simulation results for each commodity in a deposit model. The underlying assumption is that the randomly simulated deposits constitute a representative sample of all possible results. For each commodity, the report contains the following items:

12. Header identifying the commodity (Cu, in this example) to which the statistical summary applies.

13. The results of the simulation calculations are provided in the form of tables of numbers, where the amounts (Amt.) have been ordered from the smallest to the largest values. The three columns under the general heading "Unconditional" refer to the unconditional probability that includes the possibility that no deposits may exist in the area of interest. The three columns under the heading "Conditional" refer to the probability of a given amount of copper given the condition that one or more deposits actually exist.

14. The tables contain 3 columns of values, and 21 values. Total endowment simulation amounts are sorted by size from smallest to largest. The values are displayed from the smallest amounts of the distribution, and at an Index value interval of 250 (5 percentiles). Because these tables are the result of 4,999 separate simulations, the ordered data can be interpreted in terms of

probabilities. For example, the 90th percentile is represented by a Prob = 0.9000 and an Index of 500; the 50th percentile by a Prob=0.4999 and an Index of 2500 (with a value in this example of 3.8 million metric tons or more of copper); and the 10th percentile by a Prob=0.0998 with an Index of 4500 (with a value in this example of 25 million metric tons or more of copper). Values in the Unconditional table are used in the templates to construct the curves in the Cumulative Distribution Graph figure (see Part III).

15. The expected mean endowments associated with the two simulation distributions. A probability for the mean is obtained by using interpolation to determine the index value of the simulation run that falls closest in value to that of the mean.

16. Table listing the number of deposit scenarios simulated (N =), the number of times that each scenario was actually simulated (Freq(N) =), and the theoretical probability EMINERS assigned to each scenario (Prob(N) =). During execution, EMINERS applies a default distribution to the set of deposit estimate values provided by the assessment team to obtain theoretical probabilities for each deposit scenario ranging from 0 to a value equal to the largest value in a deposit estimate set. In the example, endowment simulations were run using 0 through 6 deposits and the default probabilities assigned were 0.2, 0.2, 0.15, 0.1, 0.1, 0.1, and 0.15. For more detail on the assignment of default probabilities, see Root and others (1992).

17. Number of simulations run where a 0 deposit scenario was used; used to calculate probability of having no endowment. In the example, there is a 0.2 probability that there is no copper endowment present.

18. Mean number of undiscovered deposits estimated to be present in the assessment tract.

```
                    EMINERS simulation results
                     (expressed in metric tons)

Requested by:   USGS  (1)
Assessment area:        Bravo  (2)
Data requested:         Friday, February 20, 2009 at 11:08:28 am  (3)


*******************************************************************
***    (4) 1     --- Processing Model Number (5)39 ---   Empirical        (6)
        The code name assigned to this model calculation is QQ01  (7)

        Probability of Zero Deposits = -1.0000     (8)

   (9) 039 - Porphyry Cu all-deposit-types {2008} (17-20c-21a)

        90 pct  50 pct  10 pct  Type
   (10)     0       2       6   Empirical

        Random Number Seed = 1235146108  (11)
```

```
                    Sorted simulation results for Cu
                       Order of occurrence        (12)
   (13) Unconditional                         Conditional

Prob     Index   Amt.              Prob     Index   Amt.
         (14)    (metric tons)                     (metric tons)

1.0000      0   0.000000e+000     1.0000    980   1.085429e+004
0.9500    250   0.000000e+000     0.9475   1191   2.804655e+005
0.9000    500   0.000000e+000     0.8950   1402   6.039205e+005
0.8500    750   0.000000e+000     0.8425   1613   1.043258e+006
0.8000   1000   4.553812e+004     0.7900   1824   1.543818e+006
0.7499   1250   3.628724e+005     0.7375   2035   2.100178e+006
0.6999   1500   8.275479e+005     0.6850   2246   2.802643e+006
0.6499   1750   1.345463e+006     0.6325   2457   3.672933e+006
0.5999   2000   2.019343e+006     0.5800   2668   4.449869e+006
0.5499   2250   2.822046e+006     0.5275   2879   5.592021e+006
0.4999   2500   3.852312e+006     0.4750   3090   6.643556e+006
0.4499   2750   4.818989e+006     0.4225   3301   7.871084e+006
0.3999   3000   6.227984e+006     0.3700   3512   9.330008e+006
0.3499   3250   7.543780e+006     0.3175   3723   1.080618e+007
0.2999   3500   9.241822e+006     0.2650   3934   1.299988e+007
0.2498   3750   1.102969e+007     0.2125   4145   1.588082e+007
0.1998   4000   1.386719e+007     0.1600   4356   2.046634e+007
0.1498   4250   1.814573e+007     0.1075   4567   2.756720e+007
0.0998   4500   2.512527e+007     0.0550   4778   4.445795e+007
0.0498   4750   4.095209e+007     0.0025   4989   1.812439e+008
0.0002   4998   2.880969e+008     0.0002   4998   2.880969e+008


         (15) Expected mean Cu
              Unconditional           Conditional
               1.033459e+007           1.285459e+007

              N =    0 Freq(N) =    980  (17)  Prob(N) = 0.2000
              N =    1 Freq(N) =    998       Prob(N) = 0.2000
         (16) N =    2 Freq(N) =    751       Prob(N) = 0.1500
              N =    3 Freq(N) =    481       Prob(N) = 0.1000
              N =    4 Freq(N) =    511       Prob(N) = 0.1000
              N =    5 Freq(N) =    481       Prob(N) = 0.1000
              N =    6 Freq(N) =    797       Prob(N) = 0.1500

        Mean number of deposits        2.6353   (18)
```

Input Parameters Box

Simulation Results Box

12

Part III. Creation of Tables and Graphs by Use of Excel Templates

As demonstrated in Part I, the output files resulting from running the EMINERS program are a text file (**x.emr**) and an Excel file (**x.csv**). Part II explains how to read the **x.emr** file to examine the tabular simulation results for metal and rock endowments and mean number of undiscovered deposits from EMINERS. This section demonstrates use of the Excel file (**x.csv**) to supply input to Microsoft Excel templates that create graphics and tables suitable for publication.

Templates are available to report results for one to seven mineral commodities. To select the correct template, the user can count the number of metals listed in the **x.emr** file or check **table 1** for the appropriate deposit type. For example, the "Porphyry Cu (2008), all deposit types" model (model 039; see table 1) calculates metal endowments for four commodities (copper, molybdenum, gold, silver) in addition to a rock tonnage, and so the four-metal Excel template should be used.

Templates available with EMINERS version 3.0 reside in the folder named **Templates**. Each template produces a cumulative frequency plot, a table of statistics for estimates of undiscovered deposits, and a table of resource calculations based on the Monte Carlo simulation.

Using the Templates

1. Use Excel to open the **.csv** file saved from EMINERS.
2. In the **'x'_Excell000.csv worksheet,** select all the data (range A1:F114 for a model with one metal and A1:R114 for a model with seven metals) and use the **Ctrl** + **C** keys to copy the data to the clipboard.
3. From the **Templates** folder, open the appropriate Excel template, based on the number of commodities present. If a Microsoft Excel window opens and asks about updating links, click on **Don't Update**.

This demonstration uses the four-metal template:
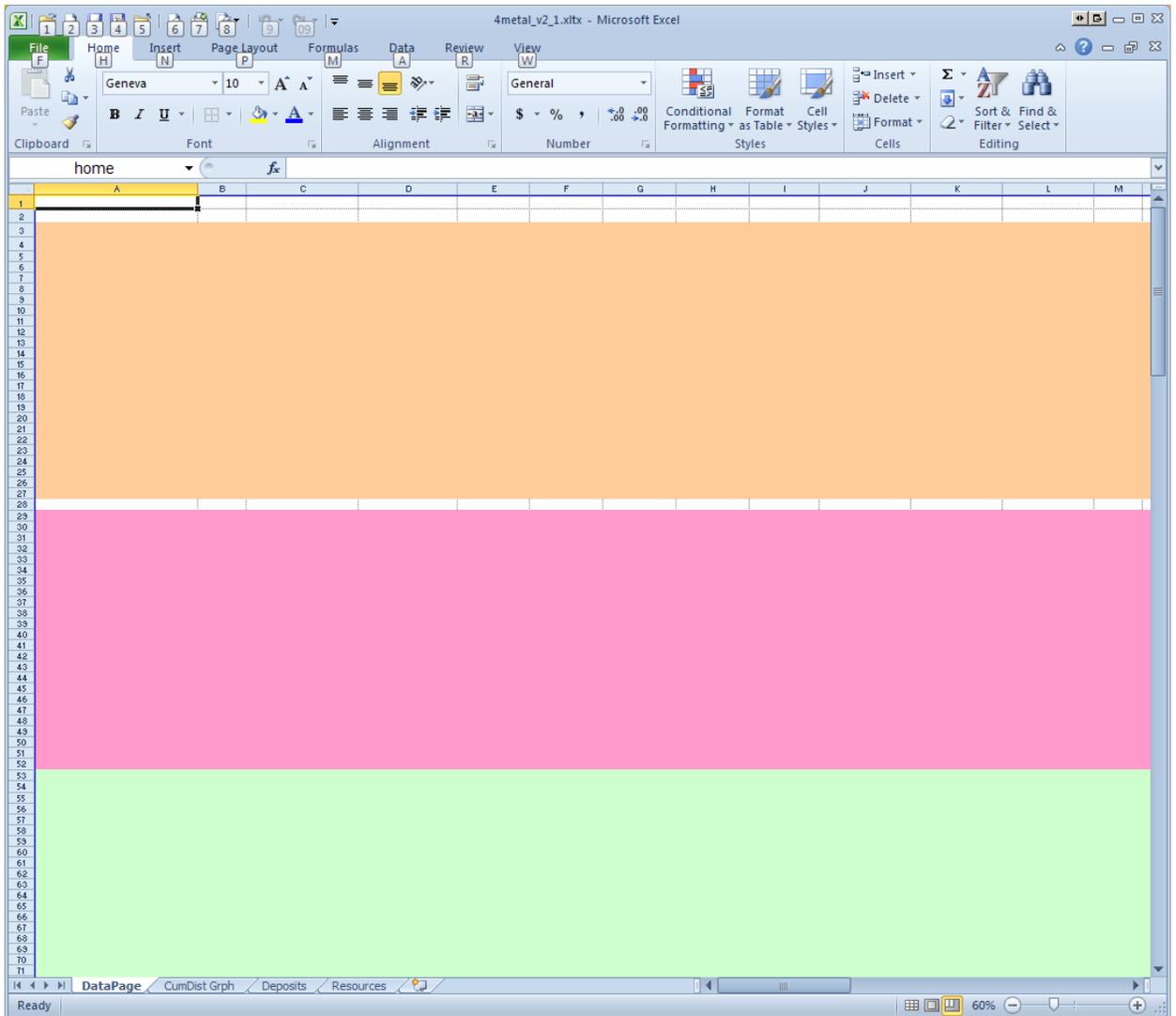
4. If the **DataPage** worksheet is not visible, scroll left and select it.

5. Click in cell **A1** if it is not already selected.

6. Right click in cell **A1**, select **Past**e.

Embedded formulae in the **DataPage** worksheet and other worksheets will automatically fill most of the remaining data cells and create the tables and chart. Limited additional user input is required and is discussed both below and in text blocks on the individual worksheets.

Graphs and Tables Available in the Templates

1. Click on TAB **CumDist Grph**.

Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in Tract Bravo. T=thousands, M=millions, B=billions, Tr=trillions
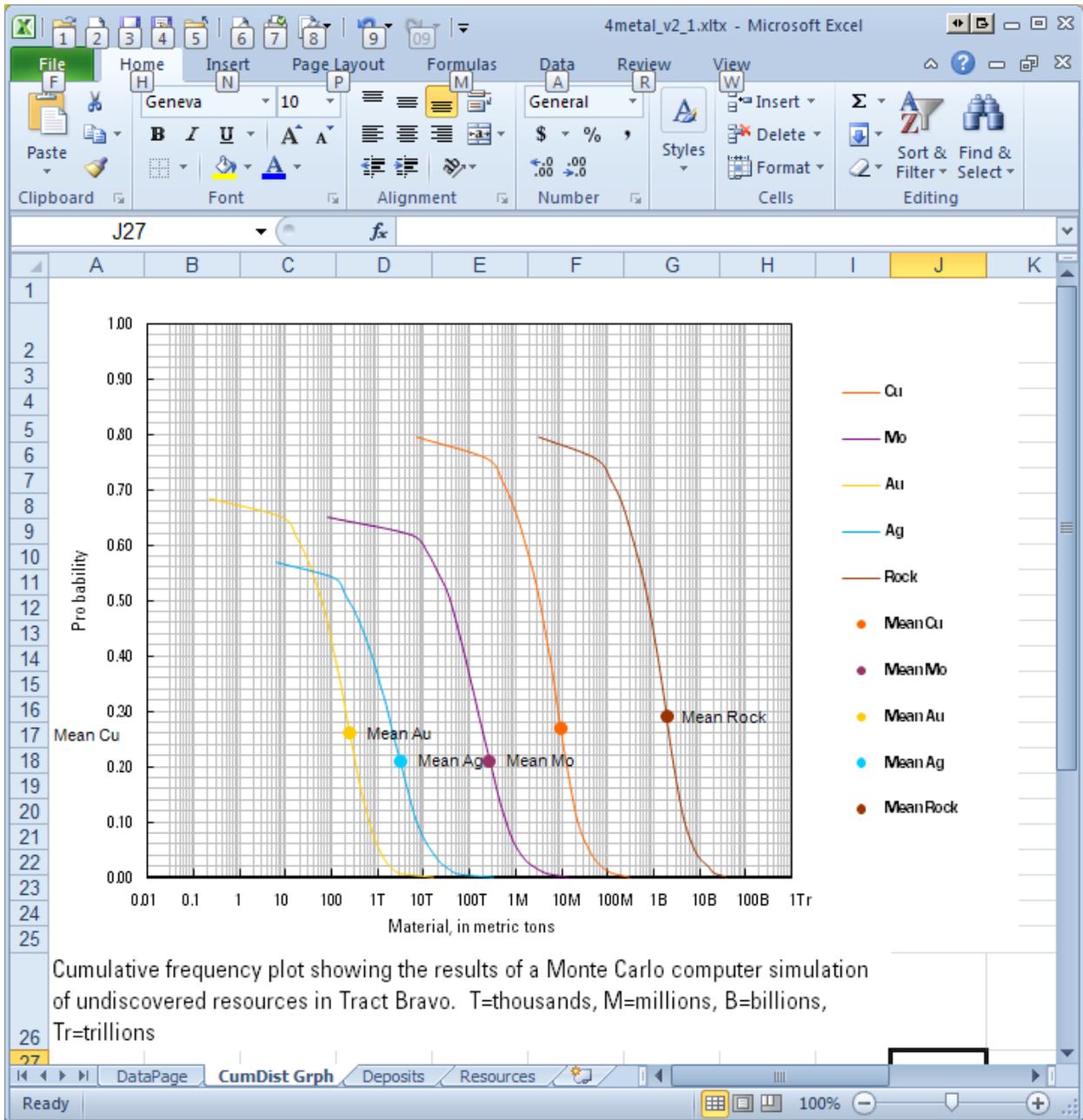
The user must confirm that all the endowment curves are fully displayed. The preset scale range for the "Material" axis will accommodate a broad range of endowment estimates. If the curves are truncated at the high or low ends of the scale range, the range must be modified. Instructions for modifying the scale range settings and the scale annotation are posted in a message box in the worksheet adjacent to the graph. The graph scale can be modified only in Excel.

A recommended procedure to use to import the graph into a Word document is also posted in the worksheet. The graph can also be exported as a .pdf file, which will require clipping.

2. Click on TAB **Deposits**.

Embedded formulae automatically fill most cells with values and insert the tract name in the table title. In cases where a three-tier approach is used to estimate undiscovered deposits, values are inserted automatically in the N05 and N01 cells, which are equal to the value appearing in the N10 cell.

A8

Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract Bravo.

[NXX - Estimated number of deposits associated with the xxth percentile, N_{und} – expected number of undiscovered deposits, s – standard deviation, Cv% - coefficient of variance, N_{known} – number of known deposits in the tract that are included in the grade and tonnage model, N_{total} – total of expected number of deposits plus known deposits, area – area of permissive tract in square kilometers, density – deposit density reported as the total number of deposits per km^2. Nund, S, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	2	6	6	6	2.6	2.2	85		2.6	0	#DIV/0!

Enter Tract Area (km^2) in cell A12:

User inputs: (1) Values for N_{known} and Tract Area need to be entered. **(2) When a 3-tier set of undiscovered deposit estimates is used rather than 5, the same value that appears in the N10 cell is automatically entered in the N05 and N01 cells.**

Export Instructions:
To export the table above to a Word document select cell B2 and use the **Ctrl+C** keys to copy the contents to the clipboard. Open the Word document and click on the the left margin where the table is to be inserted. Click on **Edit ->Paste** or use the **Ctrl+V** keys to paste the table title into the document. Return to the Excel worksheet and select cell range B3:M7. Use the **Ctrl+C** keys to copy the contents to the clipboard. Open the Word document and click at the the left margin directly below the table title and click on **Edit -> Paste** or use the **Ctrl+V** keys to paste the table into the document. After transfer embedded formulae are disabled, but cell values can be edited.

DataPage / CumDist Grph / **Deposits** / Resources

Ready   100%

Before the table is ready for export, the user must insert values in cell J2 (N_{known}) and A12 (tract area, in km^2). **A recommended procedure to use to export the table to a Word document is posted in the worksheet.**

As an option, a table is also provided in which the names and estimates of individual assessors can be reported. The table structure requires minor modification (addition of rows) to accommodate the names of all assessors and the consensus estimate.

Export Instructions:
The table below is used in cases where the names and undiscovered deposit estimates of individual assessors are to be released. In such cases the row content of the table must be adjusted by adding sufficient rows to accommodate the names of all of the assessors and the consensus estimate.
To export the table to a Word document, select only the cells in the table. Use **Ctrl+C** keys to copy the table to the clipboard. Open the Word document and click at the the left margin where the table is to be placed. Click on **Edit -> Paste** or use the **Ctrl+V** keys to paste the table into the document. Cell values can be edited after transfer.

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Individual					
Consensus					

3. Click on TAB **Resources**.

Embedded formulae automatically fill all cells with values and insert the tract name in the table title.
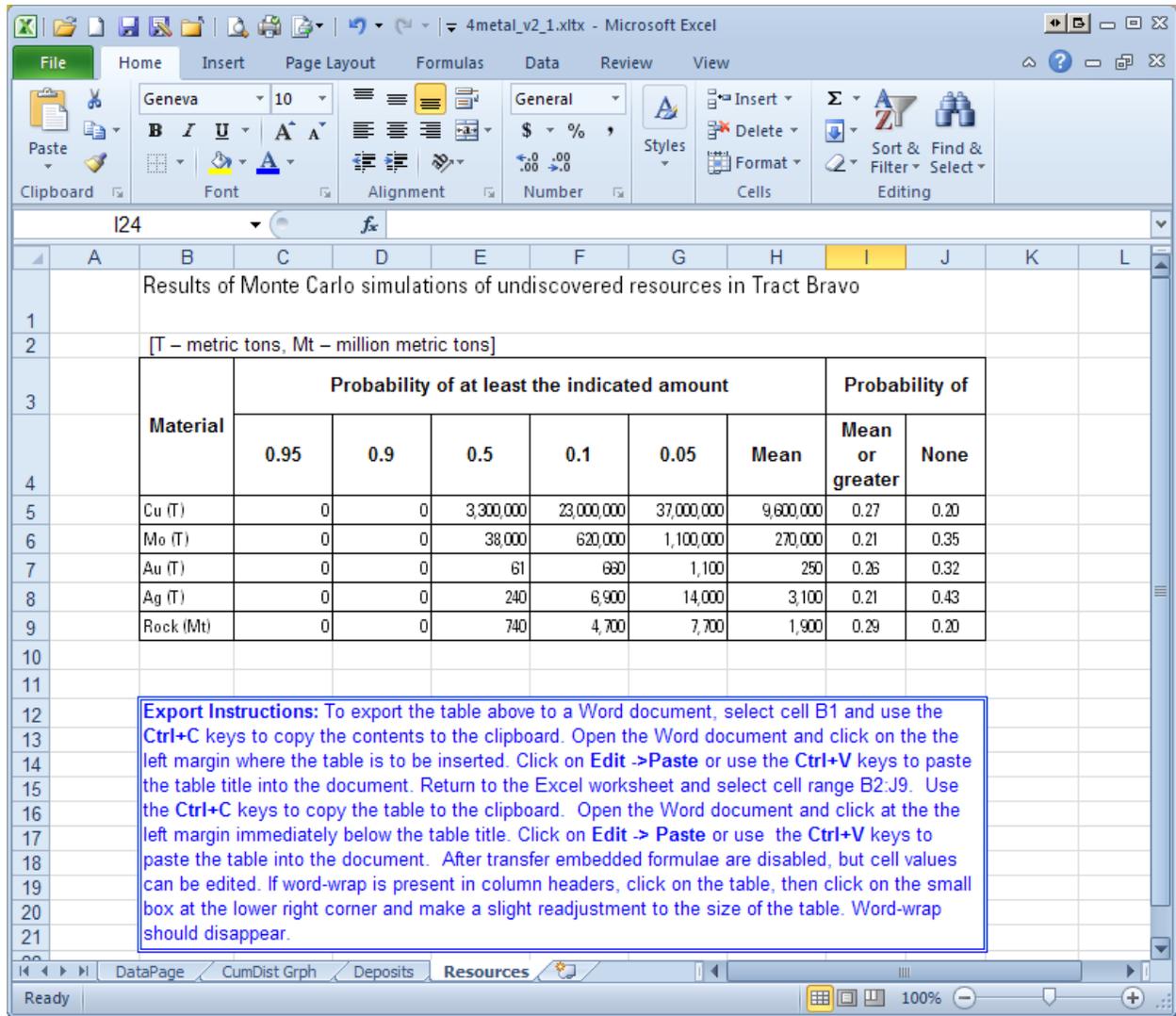
Part IV. Grade and Tonnage Models

The grade and tonnage models used in version 3.0 of EMINERS are listed in table 1.

Table 1. Listing of EMINERS model numbers, model names, commodities present, recommended template to use, and model sources.

EMINERS model number	Model name	Commodities present	Template to use	Source
1	Amorphous graphite (1992)	Amorphous graphite	1 metal	Bliss and Sutphin, 1992
2	Au-Ag-Te veins associated with alkalic rocks (1992)	Au, Ag	2 metal	Bliss and others, 1992
3	Bauxite deposits, karst-type (1986)	Al	1 metal	Mosier, 1986b
4	Bauxite deposits, laterite-type (1986)	Al	1 metal	Mosier, 1986c
5	Bedded barite (1992)	Barite	1 metal	Orris, 1992a

Table 1. Listing of EMINERS model numbers, model names, commodities present, recommended template to use, and model sources.—Continued

EMINERS model number	Model name	Commodities present	Template to use	Source
6	Besshi massive sulfide (1986)	Cu, Au, Ag, Zn	4 metal	Singer, 1986a
7	Carbonatite deposits (1998)	Nb, rare-earth oxides, P	3 metal	Singer, 1998
8	Climax Mo deposits (1986)	Mo	1 metal	Singer, Theodore, and Mosier, 1986
9	Diamond kimberlite pipes (1992)	Diamond	1 metal	Bliss, 1992d
10	Disseminated flake graphite (1990)	Disseminated flake graphite	1 metal	Sutphin and Bliss, 1990
11	Distal disseminated Ag-Au (1992)	Au, Ag	2 metal	Cox and Singer, 1992
12	Dunitic Ni-Cu (1986)	Cu, Ni, Co, Pd, Ir, Au	6 metal	Singer and Page, 1986a
13	Epithermal Mn (1986)	Mn, Fe, P	3 metal	Mosier, 1986a
14	Epithermal quartz-alunite Au (1993)	Cu, Au, Ag	3 metal	Singer, Mosier, and Menzie, 1993
15	Epithermal veins, Comstock-type (1986)	Au, Ag	2 metal	Mosier, Singer, and Berger, 1986
16	Epithermal veins, Creede-type (1986)	Au, Ag, Cu, Pb, Zn	5 metal	Mosier, Sato, and Singer, 1986
17	Epithermal veins, Sado-type (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Mosier and Sato, 1986
18	Gold antimony deposits (1993)	Sb, Au	2 metal	Berger, 1993
19	Homestake Au (1993)	Au, Ag	2 metal	Singer, Mosier, and Menzie, 1993
20	Hot-spring Au-Ag (1992)	Au, Ag	2 metal	Berger and Singer, 1992
21	Hot-spring Hg (1986)	Hg	1 metal	Rytuba, 1986
22	Komatiitic Ni-Cu (1986)	Cu, Ni, Co, Pd, Ir, Au, Pt	7 metal	Singer, Page, and Menzie, 1986a
23	Lacustrine borates (1992)	B	1 metal	Orris, 1992d
24	Laterite-saprolite Au (1992)	Au	1 metal	Bliss, 1992b
25	Lateritic Ni (1986)	Ni, Co	2 metal	Singer, 1986b
26	Low-sulfide Au-quartz veins (1986)	Au, Ag	2 metal	Bliss, 1986
27	Low-sulfide Au-quartz veins, Chugach-type (1992)	Au, Ag	2 metal	Bliss, 1992a
28	Marine bedded gypsum (1992)	Gypsum	1 metal	Orris, 1992e
29	Oolitic ironstones (1992)	Fe, Si, P, Mn, Ca, Al	6 metal	Orris, 1992b
30	Phosphate deposits, upwelling-type (1986)	P	1 metal	Mosier, 1986g
31	Phosphate deposits, warm-current-type (1986)	P	1 metal	Mosier, 1986j
32	Placer Au-PGE (1986)	Au, Ag	2 metal	Orris and Bliss, 1986
33	Placer PGE-Au (1986)	Pt, Au, Os, Ir, Pd	5 metal	Singer and Page, 1986c
34	Podiform chromite, major (1986)	Cr, Pd, Pt, Ir, Rh, Ru	6 metal	Singer, Page, and Lipin, 1986

Table 1. Listing of EMINERS model numbers, model names, commodities present, recommended template to use, and model sources.—Continued

EMINERS model number	Model name	Commodities present	Template to use	Source
35	Podiform chromite, minor (1986)	Cr, Ir, Pd, Pt, Rh, Ru	6 metal	Singer and Page, 1986b
36	Polymetallic replacement deposits (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Mosier, Morris, and Singer, 1986
37	Polymetallic veins (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Bliss and Cox, 1986
38	Porphyry Cu (2005), all deposit types	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2005
39	Porphyry Cu (2008), all deposit types	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2008
40	Porphyry Cu, BC-AK-subtype (1993)	Cu, Au, Mo, Ag	4 metal	Menzie and Singer, 1993
41	Porphyry Cu, Cu-Au-subtype (2005)	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2005
42	Porphyry Cu, Cu-Au-subtype (2008)	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2008
43	Porphyry Cu, Cu-Mo-subtype (2005)	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2005
44	Porphyry Cu, Cu-Mo-subtype (2008)	Cu, Mo, Ag, Au	4 metal	Singer, Berger, and Moring, 2008
45	Porphyry Cu, giant-Andean-subtype (2008)	Cu, Mo, Ag, Au	4 metal	Singer, Briskey, and Cunningham, 2008
46	Porphyry Mo, low-F-subtype (1986)	Mo	1 metal	Menzie and Theodore, 1986
47	Potash-bearing bedded salt (2008)	Potash	1 metal	Greta Orris, written commun.
48	Replacement Mn (1986)	Mn, Fe, P, Cu	4 metal	Mosier, 1986d
49	Replacement Sn (1986)	Sn	1 metal	Menzie and Reed, 1986a
50	Rhyolite-hosted Sn (1986)	Sn	1 metal	Singer and Mosier, 1986c
51	Sandstone-hosted Pb-Zn (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Mosier, 1986e
52	Sedimentary exhalative Zn-Pb (1993)	Ag, Cu, Pb, Zn	4 metal	Singer, Mosier, and Menzie, 1993
53	Sedimentary Mn (1986)	Mn	1 metal	Singer, Mosier, and Menzie, 1993
54	Sediment-hosted Au (1992)	Au, Ag	2 metal	Mosier and others, 1992
55	Sediment-hosted Cu (2003)	Cu, Co, Ag	3 metal	Cox and others, 2003 (revised 2007)
56	Sediment-hosted Cu, redbed-subtype (2003)	Cu, Co, Ag	3 metal	Cox and others, 2003 (revised 2007)
57	Sediment-hosted Cu, reduced facies-subtype (2003)	Cu, Co, Ag	3 metal	Cox and others, 2003 (revised 2007)
58	Sediment-hosted Cu, Revett-subtype (2003)	Cu, Ag	2 metal	Cox and others, 2003 (revised 2007)
59	Serpentine-hosted asbestos (1993)	Asbestos	1 metal	Orris, 1992c

Table 1. Listing of EMINERS model numbers, model names, commodities present, recommended template to use, and model sources.—Continued

EMINERS model number	Model name	Commodities present	Template to use	Source
60	Shoreline placer Ti (1986)	Rutile, ilmenite, leucoxene, zircon, monazite	5 metal	Attanasi and DeYoung, 1986
61	Silica-carbonate Hg (1986)	Hg	1 metal	Rytuba and Cargill, 1986
62	Simple Sb deposits (1986)	Sb	1 metal	Bliss and Orris, 1986
63	Skarn Cu (1986)	Cu, Au, Ag	3 metal	Jones and Menzie, 1986
64	Skarn Fe (1986)	Fe	1 metal	Mosier and Menzie, 1986
65	Skarn Sn (1986)	Sn	1 metal	Menzie and Reed, 1986c
66	Skarn W (1992)	W	1 metal	Menzie, Jones, and Elliott, 1992
67	Skarn Zn-Pb (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Mosier, 1986k
68	Sn greisen deposits (1986)	Sn	1 metal	Menzie and Reed, 1986b
69	Sn veins (1986)	Sn	1 metal	Menzie and Reed, 1986d
70	Solution-collapse breccia pipe uranium deposits (1992)	U	1 metal	Finch, Pierson, and Sutphin, 1992
71	Southeast Missouri Pb-Zn and Appalachian Zn (1986)	Zn, Pb, Ag	3 metal	Mosier and Briskey, 1986
72	Superior Fe and Algoma Fe deposits (1986)	Fe, P	2 metal	Mosier and Singer, 1986
73	Synorogenic-synvolcanic Ni-Cu (1986)	Cu, Ni, Co, Pd, Au, Pt	6 metal	Singer, Page, and Menzie, 1986b
74	Thorium-rare-earth veins (1986)	Th, REO	2 metal	Bliss, 1992c
75	Unconformity U-Au (1986)	U	1 metal	Mosier, 1986f
76	Volcanic-hosted magnetite (1986)	Fe, P	2 metal	Mosier, 1986h
77	Volcanogenic massive sulfide, Cyprus-type (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Singer and Mosier, 1986a
78	Volcanogenic massive sulfide, kuroko-type (1986)	Cu, Au, Pb, Ag, Zn	5 metal	Singer and Mosier, 1986b
79	Volcanogenic massive sulfide, Sierran-kuroko-type (1992)	Cu, Au, Pb, Ag, Zn	5 metal	Singer, 1992
80	Volcanogenic Mn, Cuban-type (1993)	Mn	1 metal	Singer, Mosier, and Menzie, 1993
81	Volcanogenic Mn, Cyprus-type (1988)	Mn, Fe	2 metal	Mosier and Page, 1988
82	Volcanogenic Mn, Franciscan-type (1993)	Mn	1 metal	Singer, Mosier, and Menzie, 1993
83	Volcanogenic Mn, Olympic Peninsula-type (1988)	Mn	1 metal	Mosier and Page, 1988
84	Volcanogenic U (1986)	Mo, U	2 metal	Mosier, 1986i

Table 1. Listing of EMINERS model numbers, model names, commodities present, recommended template to use, and model sources.—Continued

EMINERS model number	Model name	Commodities present	Template to use	Source
85	Wolframite-bearing quartz vein deposits (1992)	W	1 metal	Menzie, Jones, and Elliott, 1992
86	Diapiric potash (2009)	Potash	1 metal	G. Orris (written commun., 2009)
87	Diapiric potash Canadian sub-type	Potash	1 metal	G. Orris (written commun., 2009)

References Cited

The list below includes references cited in this report and sources for models listed in table 1. Many models are from U.S. Geological Survey Bulletins 1693 and 2004, which are available online at the addresses below, which are not repeated for each model citation:

http://pubs.usgs.gov/bul/b1693/

http://pubs.usgs.gov/bul/b2004/

Attanasi, E.D., and DeYoung, J.H., Jr., 1986, Grade and tonnage model of shoreline placer Ti, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 270–273.

Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23–25.

Berger, V.I., 1993, Descriptive, and grade and tonnage model for gold-antimony deposits: U.S. Geological Survey Open-File Report 93–0194, 24 p.

Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.

Bliss, J.D., 1992a, Grade and tonnage model of Chugach-type low-sulfide Au-quartz veins, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 44–46.

Bliss, J.D., 1992b, Grade and tonnage model of laterite-saprolite Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 50–51.

Bliss, J.D., 1992c, Grade and tonnage model of thorium-rare-earth veins, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 16–18.

Bliss, J.D., 1992d, Grade-tonnage and other models for diamond kimberlite pipes: Nonrenewable Resources, v. 1, no. 3, p. 214–230.

Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125–129.

Bliss, J.D., and Orris, G.J., 1986, Grade and tonnage model of simple Sb deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 184–186.

Bliss, J.D., and Sutphin, D.M., 1992, Grade and tonnage model of amorphous graphite, *in* Orris, G.J., and Bliss, J.D., eds., Industrial minerals deposit models—Grade and tonnage models: U.S. Geological Survey Open-File Report 92–437, p. 23–25.

Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkalic rocks: U.S. Geological Survey Open-File Report 92–208, 15 p.

Camm, T.W., 1991, Simplified cost models for prefeasibility mineral evaluations: U.S. Bureau of Mines Information Circular 9298, 35 p. (Also available at *http://pubs.usgs.gov/usbmic/ic-9298/html/cammfrms.htm.*)

Cox, D.P., Lindsey, D.A., Singer, D.A., Moring, Barry, and Diggles, M.F., 2003 [revised 2007], Sediment-hosted copper deposits of the world—Deposit models and database: U.S. Geological Survey Open-File Report 2003–107 version 1.3, 50 p., available at *http://pubs.usgs.gov/of/2003/of03-107/.*

Cox, D.P., and Singer, D.A., 1992, Grade and tonnage model of distal disseminated Ag-Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 20–22.

Duval, J.S., 2000, A Microsoft Windows version of the MARK3 Monte Carlo mineral resource simulator: U.S. Geological Survey Open-File Report 00–415, 1 CD-ROM. (Also available at *http://pubs.usgs.gov/of/2000/of00-415/.*)

Duval, J.S., 2012, Version 3.0 of EMINERS—Economic Mineral Resource Simulator: U.S. Geological Survey Open-File Report 2004–1344, available only at *http://pubs.usgs.gov/of/2004/1344.* (Version 3.0 of EMINERS updates version 2.0, released in 2004 as USGS OFR 2004–1344. Version 2.0 of EMINERS superseded USGS OFR 2002–0380.)

Finch, W.I., Pierson, C.T., and Sutphin, H.B., 1992, Grade and tonnage model of solution-collapse breccia pipe uranium deposits, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 36–38.

Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86–89.

Menzie, W.D., Jones, G.M., and Elliott, J.E., 1992, Tungsten—Grades and tonnages of some deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. J1–J7.

Menzie, W.D., and Reed, B.L., 1986a, Grade and tonnage model of replacement Sn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 62–63.

Menzie, W.D., and Reed, B.L., 1986b, Grade and tonnage model of Sn greisen deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 71–72.

Menzie, W.D., and Reed, B.L., 1986c, Grade and tonnage model of Sn skarn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 58–60.

Menzie, W.D., and Reed, B.L., 1986d, Grade and tonnage model of Sn veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 67–69.

Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93–0275, 9 p. (Also available at *http://pubs.usgs.gov/of/1993/ofr-93-0275/.*)

Menzie, W.D., and Theodore, T.G., 1986, Grade and tonnage model of porphyry Mo, low-F, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 120–122.

Mosier, D.L., 1986a, Grade and tonnage model of epithermal Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 166–167.

Mosier, D.L., 1986b, Grade and tonnage model of karst type bauxite deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 258–260.

Mosier, D.L., 1986c, Grade and tonnage model of laterite type bauxite deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 255–257.

Mosier, D.L., 1986d, Grade and tonnage model of replacement Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 105–107.

Mosier, D.L., 1986e, Grade and tonnage model of sandstone-hosted Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 202–204.

Mosier, D.L., 1986f, Grade and tonnage model of unconformity U-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 249–250.

Mosier, D.L., 1986g, Grade and tonnage model of upwelling type phosphate deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 234–236.

Mosier, D.L., 1986h, Grade and tonnage model of volcanic-hosted magnetite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 172–174.

Mosier, D.L., 1986i, Grade and tonnage model of volcanogenic U, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 162–164.

Mosier, D.L., 1986j, Grade and tonnage model of warm-current type phosphate deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 237–238.

Mosier, D.L., 1986k, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90–93.

Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224–226.

Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of Fe skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 94–97.

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101–104.

Mosier, D.L., and Page, N.J, 1988, Descriptive and grade-tonnage models of volcanogenic manganese deposits in oceanic environments—A modification: U.S. Geological Survey Bulletin 1811, 28 p. (Also available at *http://pubs.usgs.gov/bul/b1811/b1811.pdf.*)

Mosier, D.L., and Sato, Takeo, 1986, Grade and tonnage model of Sado epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models, U.S. Geological Survey Bulletin 1693, p. 155–157.

Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade and tonnage model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 146–149.

Mosier, D.L., and Singer, D.A., 1986, Grade and tonnage model of Superior Fe and Algoma Fe deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 228–230.

Mosier, D.L., Singer, D.A., Bagby, W.C., and Menzie, W.D., 1992, Grade and tonnage model of sediment-hosted Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 26–28.

Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151–153.

Orris, G.J., 1992a, Grade and tonnage model of bedded barite, *in* Orris, G.J., and Bliss, J.D., eds., Industrial minerals deposit models—Grade and tonnage models: U.S. Geological Survey Open-File Report 92–437, p. 40–42. (Also available at *http://pubs.usgs.gov/of/1992/ofr-92-0437/.*)

Orris, G.J., 1992b, Grade and tonnage model of oolitic ironstones, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 41–43.

Orris, G.J., 1992c, Grade and tonnage model of serpentine-hosted asbestos, *in* Orris, G.J., and Bliss, J.D., eds., Industrial minerals deposit models—Grade and tonnage models: U.S. Geological Survey Open-File Report 92–437, p. 2–4. (Also available at *http://pubs.usgs.gov/of/1992/ofr-92-0437/.*)

Orris, G.J., 1992d, Preliminary grade and tonnage model of lacustrine borates, *in* Orris, G.J., and Bliss, J.D., eds., Industrial minerals deposit models—Grade and tonnage models: U.S. Geological Survey Open-File Report 92–437, p. 56–59. (Also available at *http://pubs.usgs.gov/of/1992/ofr-92-0437/.*)

Orris, G.J., 1992e, Preliminary grade and tonnage models of marine bedded gypsum, *in* Orris, G.J., and Bliss, J.D., eds., Industrial minerals deposit models—Grade and tonnage models: U.S. Geological Survey Open-File Report 92–437, p. 53–55. (Also available at *http://pubs.usgs.gov/of/1992/ofr-92-0437/.*)

Orris, G.J., and Bliss, J.D., 1986, Grade and tonnage model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261–264.

Root, D.H., Menzie, W.D., and Scott, W.A., 1992, Computer Monte Carlo simulation in quantitative resource estimation: Nonrenewable Resources, v. 1, no. 2, p. 125–138.

Root, D.H., Scott, W.A., Jr., and Selner, G.I., 1996, Computer program for aggregation of probabilistic assessments of mineral resources: U.S. Geological Survey Open-File Report 96–94, 1 diskette.

Rytuba, J.J., 1986, Grade and tonnage model of hot-spring Hg, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 178–179.

Rytuba, J.J., and Cargill, S.M., 1986, Grade and tonnage model of silica-carbonate Hg, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 181–182.

Singer, D.A., 1986a, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136–138.

Singer, D.A., 1986b, Grade and tonnage model of lateritic Ni, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 252–254.

Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 29–32.

Singer, D.A., 1998, Revised grade and tonnage model of carbonatite deposits: U.S. Geological Survey Open-File Report 98–235, 7 p.

Singer, D.A., Berger, V.I., and Moring, B.C., 2005, Porphyry copper deposits of the world—Database, map, and grade and tonnage models: U.S. Geological Survey Open-File Report 2005–1060, 9 p. and data files, available only online at *http://pubs.usgs.gov/of/2005/1060/.* (Superseded by USGS Open-File Report 2008–1155.)

Singer, D.A., Berger, V.I., and Moring, B.C., 2008, Porphyry copper deposits of the world—Database and grade and tonnage models, 2008: U.S. Geological Survey Open-File Report 2008–1155, 45 p. and data files, available only online at *http://pubs.usgs.gov/of/2008/1155/.*

Singer, D.A., Briskey, J.A., and Cunningham, C.G., 2008, Grade and tonnage model of giant porphyry copper deposits, Appendix 1 *of* Cunningham, C.G., and others, Quantitative mineral resource assessment of copper, molybdenum, gold, and silver in undiscovered porphyry copper deposits in the Andes Mountains of South America: U.S. Geological Survey Open-File Report 2008–1253, p. 64–67, available on CD-ROM and at *http://pubs.usgs.gov/of/2008/1253/.*

Singer, D.A., and Menzie, W.D., 2010, Quantitative mineral resource assessments—An integrated approach: New York, Oxford University Press, 219 p.

Singer, D.A., and Mosier, D.L., 1986a, Grade and tonnage model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131–135.

Singer, D.A., and Mosier, D.L., 1986b, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190–197.

Singer, D.A., and Mosier, D.L., 1986c, Grade and tonnage model of rhyolite-hosted Sn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 169–171.

Singer, D.A., Mosier, D.L., and Menzie, W.D., 1993, Digital grade and tonnage data for 50 types of mineral deposits: U.S. Geological Survey Open-File Report 93–280, version 1.0, on CD-ROM. (Also available at *http://pubs.usgs.gov/of/1993/ofr-93-0280/.*)

Singer, D.A., and Page, N.J, 1986a, Grade and tonnage model of dunitic Ni-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 24–27.

Singer, D.A., and Page, N.J, 1986b, Grade and tonnage model of minor podiform chromite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 34–38.

Singer, D.A, and Page, N.J, 1986c, Grade and tonnage model of placer PGE-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 265–269.

Singer, D.A., Page, N.J, and Lipin, B.R., 1986, Grade and tonnage model of major podiform chromite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 38–44.

Singer, D.A., Page, N.J, and Menzie, W.D., 1986a, Grade and tonnage model of komatiitic Ni-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 18–23.

Singer, D.A., Page, N.J, and Menzie, W.D., 1986b, Grade and tonnage model of synorogenic-synvolcanic Ni-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 28–31.

Singer, D.A., Theodore, T.G., and Mosier, D.L., 1986, Grade and tonnage model of Climax Mo deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 73–75.

Sutphin, D.M., and Bliss, J.D., 1990, Disseminated flake graphite and amorphous graphite deposit types—An analysis using grade and tonnage models: CIM Bulletin, v. 83, no. 940, p. 85–89.