



Texas Culvert and Bridge Deterioration Models

Implementation Manual

Product 0-6979-P2
Cooperative Research Program

UNIVERSITY OF TEXAS AT SAN ANTONIO
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<p>This report consists of a manual to be used in conjunction with Product 0-6979-P2, a set of 9 Excel workbooks that contain implemented bridge and culvert deterioration models. NBI/PonTex data items modeled were: Item 58, Deck Rating (11 models), Item 59, Superstructure Rating (17 models) Item 60, Substructure Rating (10 models) and Item 62, Culvert Rating (8 models). Product 0-6979-P2 workbooks automatically update all network deterioration results when the current network condition is updated. The culvert results also include an extra worksheet with cost estimates to rehabilitate culverts predicted to have ratings of 4 or less.</p> <p>This manual explains the basic organization of the workbooks and the type of forecasts and deterioration curves they provide. More importantly, it explains how to retrieve from PonTex the updated on- and off-system current network conditions, for each rating, each modeling family, and each age group, in terms of number of culverts, number of bridges, and total bridge area. Product 0-6979-P2 is an infrastructure management tool to assist TxDOT in bridge and culvert management.</p>			
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This report is not intended for construction, bidding, or permit purposes.

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Implementation Products Objective and Contents


Project 0-6979 implementation Product 2 consists of a set of Excel workbooks that forecast future bridge and culvert network deterioration. Product 2 includes culvert cost evaluations, even though cost evaluations were not included in contractual tasks. Bridge costs, however, are more complex to develop and implement, since they combine forecasts for 3 different condition ratings.


Chapter 9 of Report 0-6979-1, *Deterioration Forecasts and Cost Estimates of Texas Bridges and Culverts Using National Bridge Inventory Data*, outlines a methodology to calculate rehabilitation costs based on the deterioration results delivered in Product 2. The aforementioned report includes cost estimates for forecasts prepared with 2019 bridge data.

It is recommended to browse the contents of the folder containing Product 2 workbooks and its list of files while reading the remainder of this section.

The following models were implemented in Product 2, for the PonTex/NBI 4 condition ratings listed below, together with the screen capture of the file names. All workbooks come with forecasts prepared with 2019 data. The first sheet in all workbooks is the DOT form 1700.7, followed by a hyperlinked table of contents.


Item 58—Deck Rating

 0-6979 Product2 Off-System Deck.xlsx.....7 models

 0-6979 Product2 On-System Deck.xlsx 4 models


Item 59—Superstructure Rating

 0-6979 Product2 Off-system Superstructure.xlsx..... 7 models

 0-6979 Product2 On-System Superstructure.xlsx..... 7 models


 0-6979 Product2 Superstructure WS Truss Timber.xlsx..3 models (on&off-system data)

Item 60—Substructure Rating

 0-6979 Product2 Off-System Substructure.xlsx..... 6 models

 0-6979 Product2 On-System Substructure.xlsx 4 models

Item 62—Culvert Rating

 0-6979 Product2 Off-System Culverts.xlsx.....4 models with cost forecasts

 0-6979 Product2 On-System Culverts.xlsx.....4 models with cost forecasts

All results in the implementation products are based on Markov transition probability matrices, which are also included in Product 2 workbooks. The transition probabilities were calculated from 19 years of inspection data provided by TxDOT. These data were organized into a historical inspection data set of almost one million records. The Markov process was applied to obtain deterioration estimates every 2 years. The modeling methodology and results are discussed in Research Report 0-6979-1.

Given the massive amount of data and the complexity of the calculations involved, all data management and all data analyses and calculations were developed in SAS™. The research results implementation, however, does not required complex software. It is accomplished through the 9 Excel workbooks listed

above, which will update all network condition forecasts when the current network condition and the current year are updated as explained next.

General Workbooks Organization

This section summarizes the organization of the 9 Excel Workbooks containing the implementation Product 2, and explains which PonTex variables are necessary to retrieve in order to update the current breakdown of ratings by number of bridges or culverts, and by bridge area, for the modeling families and age groups. All network-level forecasts, graphs and cost estimates are automatically updated in Excel. Product 2 was delivered with forecasts prepared for 2019 data.

It is recommended to open one of the workbooks and refer to it while reading this manual. We recommend opening either on- or off-system superstructure workbook, as both have models by age groups and by families.

Model Worksheets

The 3 bridge ratings are organized in separate workbooks for on-and off-system. The workbooks first worksheet is Form DOT 1700.7. Next is a worksheet containing a hyperlinked table of contents. For each on- and off-system model family and age group, there is one worksheet of the general format depicted in Figure 1. In addition, there is a model developed for the aggregated on- and off-system data. All worksheets of this type have green tabs.

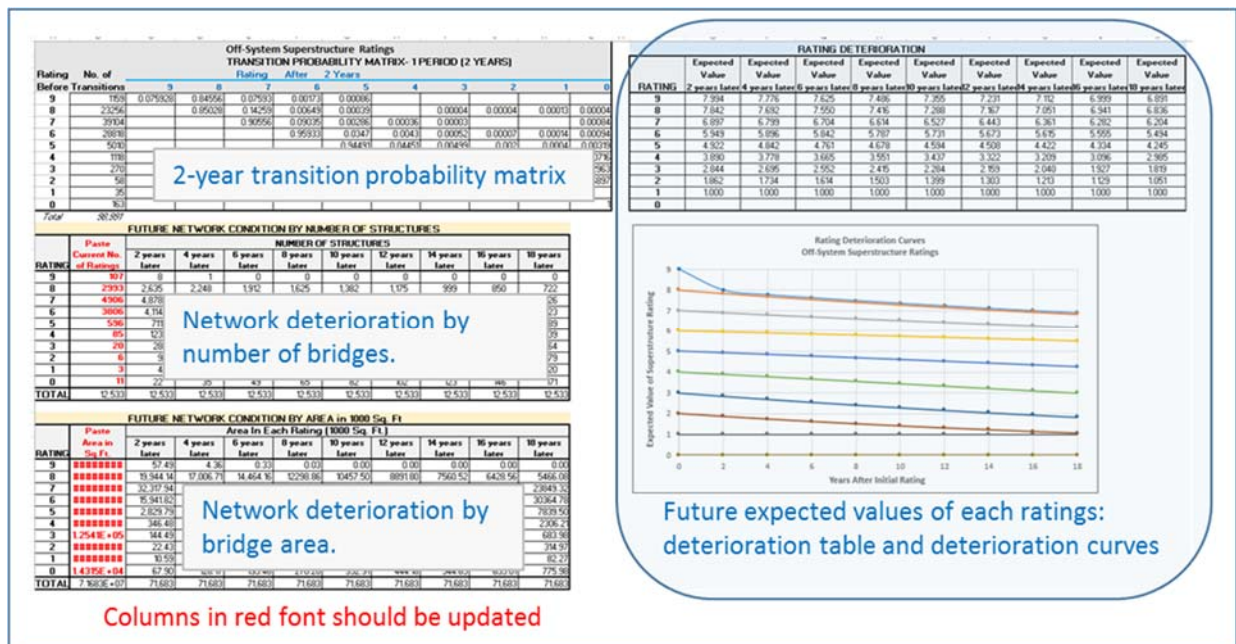


Figure 1 Model Results Worksheet Organization—Bridge Ratings

The top left table is the 2-year Markov transition probability matrix developed for each model. Each cell shows the probability of the rating in the first column either remaining as, or decreasing to, the rating in the blue row, after 2 years. Below the Markov matrix are 2 tables with the network deterioration forecasts

every 2 years, up to 18 years. The top table contains the predicted number of bridges at each rating, and the bottom table contains the total bridge area predicted for each rating. When the current condition is updated in the columns in red font, embedded calculations apply the Markov process to the current data, recalculate the network forecasts in the tables, and update the network deterioration curves (discussed later).

Important: the red font column containing the current bridge area breakdown by rating is in square feet, to facilitate the update. The results of network deterioration every 2 years are in 1000 square feet.

The top right table shows the rating deterioration, as future expected values of the ratings. The rating deterioration curves are plotted from this the table. Future expected values of the ratings are a function of the Markov transition probabilities only, so they do not update when the network condition is updated in the two red font “B” columns in the 2 tables on the left. The only way to update the expected rating values is to redo all the transition probabilities calculations, when more data becomes available. This is recommended every 10 years, as discussed in Research Report 0-6979-1.

The culvert models worksheets are similar to Figure 1, except that they do not have network deterioration tables by area, since one of the 2 variables needed to estimate culvert area were missing in a considerable portion of the data.

Network Deterioration Charts and Curves

Each on- and off-system workbook has three worksheets containing bar charts and deterioration curves. The worksheets tabs are blue and are titled as illustrated below:

By age groups:	Current vs 10 yr age	Net. Det curves age % bridges	Net. Det. curves age %area
By families:	Current vs 10-yr span	Network Det. span % bridges	Network Det. span % area

The tabs titled “Net. Det. Curves %...” or similar abbreviations contain the network deterioration curves by percent bridges and percent bridge area. Figure 2 shows an example of such curves, which are implemented for all age groups and families, and the aggregated on- and off-system models. These curves will update when the current network condition is updated in the model worksheets (see Figure 1).

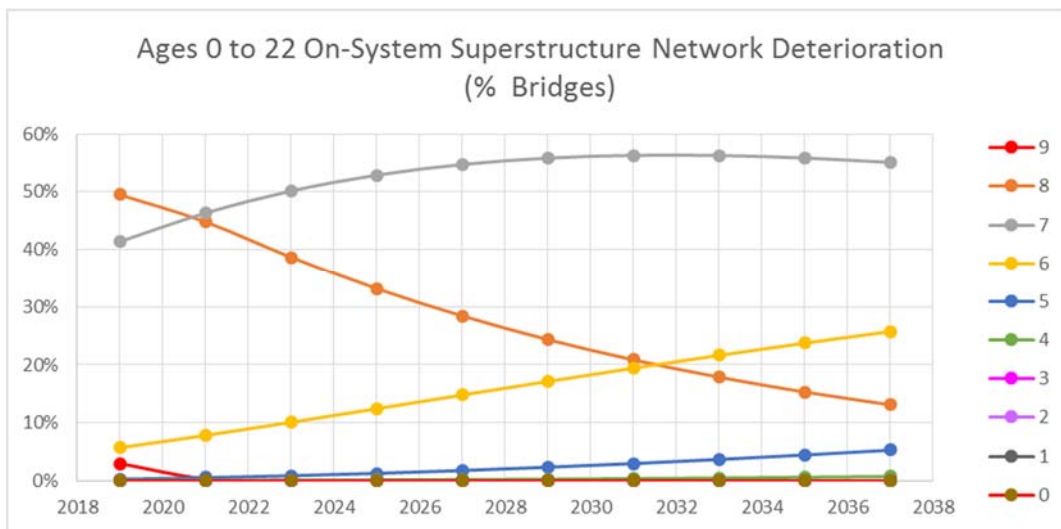


Figure 2 Example of Network Deterioration Curves

The tabs titled “Current vs 10yr...” contain bar charts comparing current and 10-year forecasts of aggregated on- or off-system network condition to network condition by age groups. Workbooks that also contain models by families have analogous worksheets by families.

Figure 3 illustrates the charts comparing current network condition to the 10-year forecasts, by percent bridges or culverts (top), and percent bridge areas (bottom). When comparisons among families are affected by differences in family age, there is note in the worksheet to that effect. These graphs will update when the current network condition is updated in the model worksheets (green tabs).

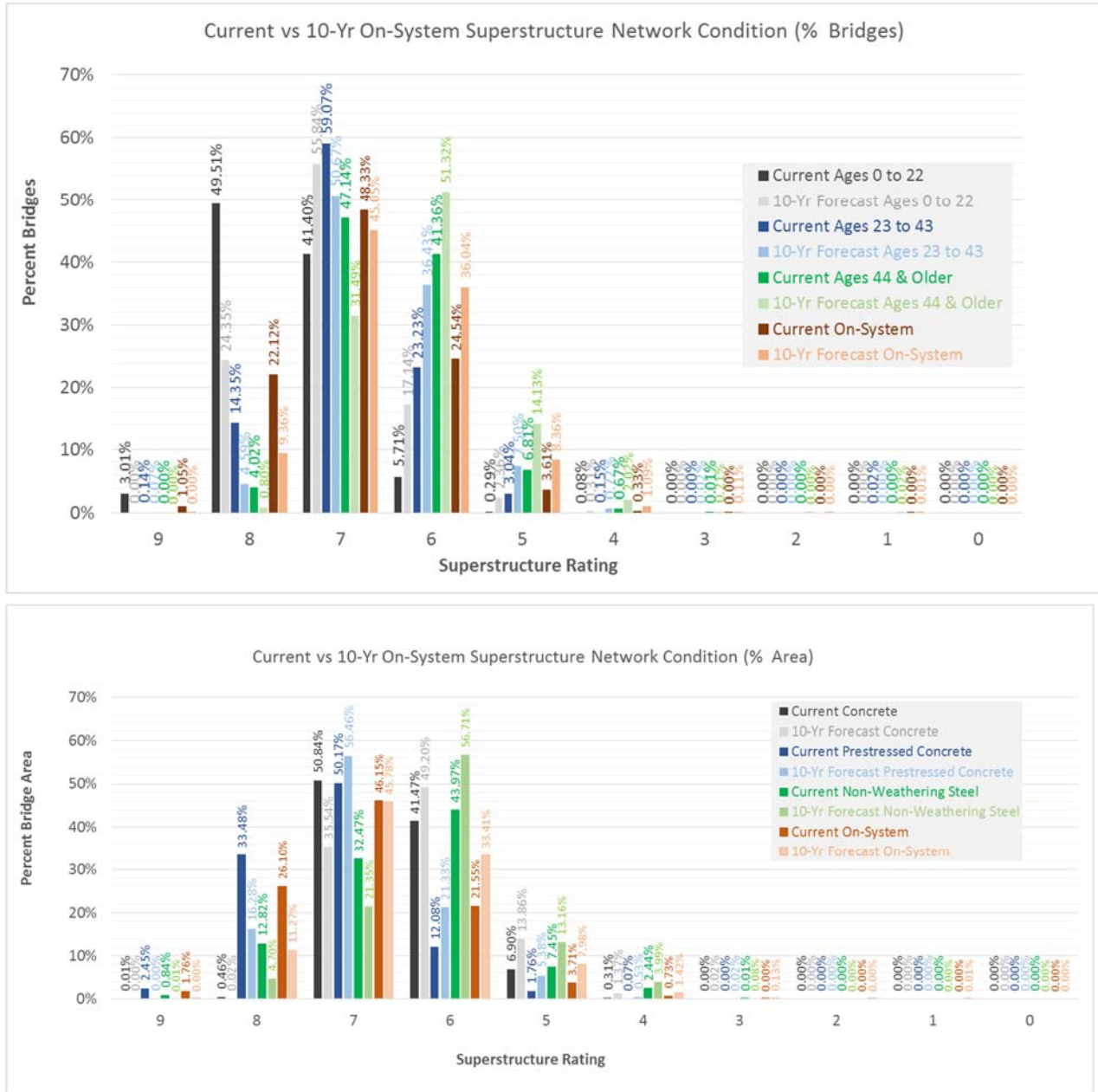


Figure 3 Examples of Charts Comparing Current to 10-Year Network Condition by Age Groups (Top) and by Families (Bottom)

Updating the Network Condition Curves and Forecasts

This section lists the PonTex items used to split the data into age groups and families for the models, explaining how to update the current network condition. It is recommended to open one of the workbooks and refer to it while reading this section.

Update the current year

Type the current year in all worksheets containing network deterioration curves, by percent bridge area and by percent bridges or culverts (blue tabs).

Figure 4 shows a screen capture of a typical worksheet cell containing the current year, and the typical worksheet blue tabs. The yellow cell is hyperlinked in the table of contents.

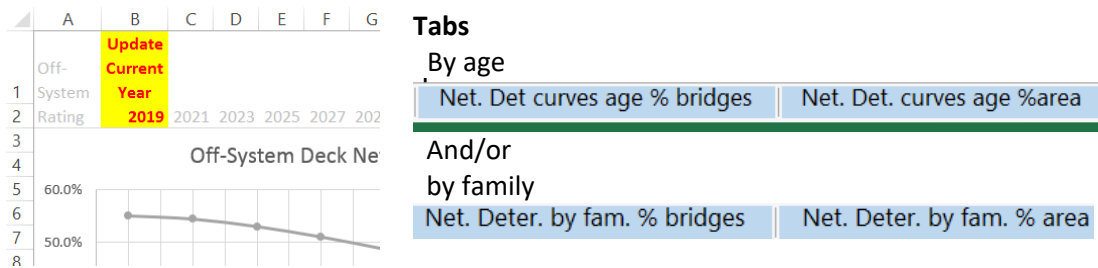


Figure 4 Screen Capture of a Worksheet Containing Network Deterioration Curves

Calculate current bridge and culvert ages

Create a column for the current age in both on- and off-system PonTex tables, by subtracting either the year built or the year reconstructed from the current year. Variables are:

Year built PonTex Item 27
 2019 Access data tables column: 27 Yr Built.

Year reconstructed PonTex Item 106
 2019 Access data tables column: 106 Yr Reconstr.

Update bridge area

Create a column with bridge area by multiplying the following variables and dividing by 10:

PonTex Item 49 — Structure Length (XXXXXX feet)
 2019 Access data tables column: 49 Str Lgth

PonTex Item 52 — Deck Width, Out-to-Out (XXX.X feet). The decimal point is assumed, hence the need to divide by 10.
 2019 Access data tables column: 52 Deck Width

Current condition updates by age and by aggregated on- and off-system data

Model worksheets have green tabs and are organized as discussed before and summarized in Figure 1. The two columns containing current bridge or culvert counts by rating, and the total bridge area by rating, should be updated when new PonTex data becomes available.

In addition to age groups and modeling families, all ratings were also modeled with aggregated on- and off-system data. Retrieve the total number of bridges or culverts, and total bridge area by each rating from the BRGON and BRGOFF Access tables and paste the updated breakdown by rating in the worksheets with green tabs titled “On-System” and “Off-System” in all workbooks, except the one titled “0-6979 Product2 Superstructure WS Truss Timber.xlsx.”

Prepare an Access query to subset current on- and off-system data by the on- and off-system age groups indicated below in the screen captures of Product 2 worksheet tabs. Retrieve the total number of on- and off-system bridges, culverts, and total bridge area by each rating in each age group, and paste the updated breakdowns in the corresponding worksheets in all workbooks except “0-6979 Product2 Superstructure WS Truss Timber.xlsx.”

Bridge or culvert count by rating: paste in columns B19 to B28.
 Bridge area by rating: paste in columns B34 to B43.

BRIDGES

CONTENTS	On-System	On-System 0 to 22	On-System 23 to 43	On-System 44&Older
CONTENTS	Off-System	Off-System 0 to 16	Off-System 17 to 34	Off-System 35&Older

CULVERTS

CONTENTS	On-System	0 to 32	33 to 48	49 & Older
CONTENTS	Off-System	0 to 17	18 to 34	35 & Older

Current condition updates by model families

Workbooks that do not contain models by families are:

- On- and off-system culvert rating.
- On-system deck rating.
- On-system substructure rating.

Updating off-system substructure families

Prepare an Access query to subset the off-system data table into 2 families, “bridges over water” and “bridges over dry land,” based on PonTex Item 61, Channel Protection, stored in the 2019 Access table column “61 Chan Prot.” Any value other than “N” indicates a bridge over water.

Retrieve the total off-system bridge count and the total area by substructure rating for each family and paste in the corresponding worksheets in the workbook titled “0-6979 Product2 Off-System Substructure.xlsx:”

Off-System Over Water	Off-System Over Dry Land
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Updating on- and off-system superstructure families

Superstructure families are based on PonTex Item 43.1—Structure Type, Main Span. This item is stored in 2019 Access column “43 1 Mn Span Ty.” Item 43.1 is a 4-character variable; the 3rd and 4th digits describe

80 member types. These were grouped into 5 families to ensure enough data to develop valid Markov transition probability matrices: concrete, prestressed concrete, steel, weathering steel, timber and truss, as depicted in Table 1. Member type codes not listed in this table, could not be modeled as families due to insufficient data.

In order to update the current superstructure condition by bridge count and bridge area, create another Access column containing only the 3rd and 4th digits of column “43 1 Mn Span Ty.” Then create one Access query for each family, according to the values listed in Table 1. Concrete, prestressed concrete and steel (non-weathering) had enough data to be modeled separately by on- and off-system. Timber, truss and weathering steel were modeled with aggregated on- and off-system to ensure sufficient rating transitions to obtain 3 valid Markov transition probability matrices. Timber, truss and weathering steel are delivered in a separate workbook.

Table 1 Superstructure Main Span Type Families

Family	3 rd and 4 th digits of Item 43.1, Access column 43 1 Mn Span Ty								
Weathering Steel	01	02	03	04	05	06	07	08	09
Steel (non-weathering)	11	12	13	14	15	16	17	18	19
Concrete	21	22	23	24	25	26	27	28	29
Pre-stressed concrete	30	31	32	33	34	35	36	37	38
	39								
Timber	41	42	43	49					
Truss	61	62	63	64	65	66	67	68	
	71	72	73	74	75	76	77	78	79
	81	82	83	84	85	86	87	88	89
	91	92	93	97	98				

For each family listed in Table 1, retrieve the total on- and off-system bridge count and the total area by superstructure rating. Paste results for concrete, steel and prestressed concrete in the corresponding worksheets of workbooks titled “0-6979 Product2 Off-System Superstructure.xlsx,” and “0-6979 Product2 On-System Superstructure.xlsx:”

On-System Concrete	On-System Prestress Concrete	On-System Steel
Off-System Concrete	Off-System Prestress Concrete	Off-System Steel

Add the on-system and the off-system bridge counts and total bridge area by rating for truss, then repeat for weathering steel and timber. Paste each total the in the corresponding worksheets of workbook titled “0-6979 Product2 Superstructure WS Truss Timber.xlsx:”

Weathering Steel	Truss	Timber
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Updating off-system deck families

Deck families were developed based on Item 107.1 — Main Span. This item is stored in 2019 Access column: 107 1 Deck Ty MSp. This is a one-character variable that takes the 10 values depicted in the

second column of Table 2. These values were grouped into 3 families to ensure enough data to develop valid Markov transition probability matrices. Table 2 also shows the number of data points in the inspection history database.

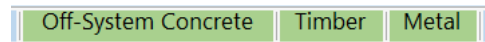
On-system decks are nearly all concrete, hence there are no on-system models by deck type families (see Table 2). Timber and metal decks were modeled using aggregated on- and off-system data in order to increase the number of data points. As depicted in Table 2, nearly all data points for timber and metal decks are off-system. Therefore, they represent off-system conditions for practical purposes, so were included in the of-system deck workbook.

Table 2 PonTex Item 107.1, Deck Structure Type, Main Span

Deck Material (Main Span)	Item 107.1	Off-System Ratings		On-System Ratings		Total	
		Number	Percent	Number	Percent	Number	Percent
Concrete	1,2	92,395	75.78%	200,581	98.96%	292,976	90.25%
Metal	3,4,5,6,7	5,472	4.49%	796	0.39%	6,268	1.93%
Timber	8	21,738	17.83%	91	0.04%	21,829	6.72%
Other	9	1,742	1.43%	627	0.31%	2,369	0.73%
N/A	N or blank	580	0.48%	599	0.30%	1,179	0.36%
<i>All materials</i>		<i>121,927</i>		<i>202,694</i>		<i>324,621</i>	

Note: this table is a copy of Table 8.2 in Report 0-6979-1.

In order to update the current condition breakdown by bridge count and bridge area, open the off-system PonTex data table BRGOFF and prepare Access queries to get data tables for concrete, metal, and timber families based on Item 107.1, as listed in Table 2. Retrieve the total bridge count and total bridge area by deck rating for each family, and paste onto the corresponding worksheets of workbook titled "0-6979 Product2 Off-System Deck .xlsx:"



Results that will automatically update

- Network deterioration tables in model worksheets, every 2 years for 18 years (green tabs). These are the 2 left tables in Figure 1.
- Network deterioration curves by percent bridges or percent culverts (blue tabs).
- Network deterioration curves by percent bridge area (blue tabs). Example: Figure 2.
- Current vs 10-year forecast bar charts (blue tabs). Example: Figure 3.