Old and Middle River Flow Review:

USGS Gauge Readings versus Index Calculations for 2011 through 2017

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October 2017

1. Introduction

This report will demonstrate the strong flow correlation between the United States Geological Survey gages at the Old and Middle Rivers (USGS OMR), and the OMR Index calculations, which have been used by the State Water Project and the Central Valley Project (the Projects) to operate to and comply with Old and Middle River (OMR) flow requirements. The results of the two different methodologies for determining OMR will be compared with daily, 5-day average, and 14-day average values, and will demonstrate a close correlation and tracking between the two methodologies. The time-span will be from December to June of the Water Years 2011 to 2017 and gives a background view and general effectiveness of using the OMR Index.

The difference between the methodologies is that the USGS OMR values are based on tidally filtered hourly flow values of Old and Middle Rivers near Bacon Island, whereas the Index methodology uses an empirical equation based on net flows into and out of the Southern Delta.

The USGS OMR flow values have been difficult for the Projects to operate to, in large part because the tidally filtering calculation is lagged by three days. What's more, atmospheric conditions exert an unpredictable influence on OMR values and missing data introduces errors.

By contrast, the OMR Index is much easier to work with because the San Joaquin River at Vernalis (VNS) gage used in the OMR Index equation is located upstream of the Delta and is therefore not affected significantly by tidal effects or atmospheric conditions and has only a one-day delay in the OMR Index equation. Using prior day flows from the VNS gage allows the Projects' operations to be more predictable since current day exports can be closely controlled.

Through regression analysis and empirical graphs, this report will show that the OMR Index method produces results that are closely correlated with values from the USGS OMR. And since the Index method can be used to closely approximate the USGS OMR flow values over an averaging period, the Index method is a satisfactory alternative to using the lagged USGS OMR flow data for real-time operations.

2. Objectives

This report will show a close correlation between the USGS OMR and OMR Index methodologies by presenting regression graphs and time-series data across daily, 5-day, and 14-day running averages. Data from water years 2011 to 2017 was collected for both United State Geological Survey (USGS) tidally filtered data and OMR Index flow components, then graphed for regression analysis and displayed in a time-series for each water year when fish protection regulations were in effect. The data for both methodologies was obtained from CDEC and the USGS websites, which receive the data from gages operated by the USGS, Bureau of Reclamation, and the Department of Water Resources. A close

correlation between the two methodologies suggests that the OMR Index is a close and acceptable estimation for the USGS OMR values. Currently, compliance with OMR requirements is based on the USGS OMR values, and due to the difficulties stated above with USGS OMR values, the Projects' ability to comply with, or demonstrate compliance with, the OMR requirements can at times be out of the Projects' control.

3. Background

The use of OMR flows was introduced by the Fish and Wildlife Service and the National Marine Fisheries Service in their Biological Opinions on the Long-Term Operations of the Central Valley Project and State Water Project. These Biological Opinions imposed additional constraints on the Projects' exports during December to June under what are known as Reasonable and Prudent Alternatives (RPAs) for protected fish species such as delta smelt, steelhead, and winter-run salmon. Whereas the D1641 Bay-Delta Standards (issued by the State Water Resources Control Board) generally constrain the Projects by Delta outflow and export-to-inflow ratio requirements during the fish protection season, the Biological Opinions use OMR flow restrictions for some fish protections.

OMR flows, as a concept, are meant to represent the direction and magnitude of flows in the South Delta between the Projects' export facilities and the lower San Joaquin River. The flows are dependent on factors such as flow into the Delta from tributaries and flows exported from the Delta by the Projects, but are also influenced by atmospheric pressure, spring-neap tidal cycles, diversions by local users of water, and the wind. Actual measurements on the Old and Middle river corridors are made through acoustic velocity meters maintained by the USGS and located near Bacon Island for both river corridors.

The USGS OMR values are calculated as the sum of the tidally filtered flow estimates of the two USGS stations. Since calculations for current day values require 72 hours of data for each of the USGS stations for the tidally averaging procedure, it is impossible to get the USGS OMR value for current day operations. Due to this lag in available data, it was necessary to develop an alternative methodology in order to operate under real time conditions given the dynamic environment.

Various models and regression relationships have been used to simplify the estimation of OMR flows. The one that is used in the Projects' daily operations is the OMR Index, based on an equation developed by Dr. Paul Hutton with Metropolitan Water District (MWD 2008). Previous comparisons of the index equations to USGS OMR have shown close tracking (Guerin, 2014); hence the OMR Index has been used by the Projects for daily operations.

4. Methodology

4.1. Data

Data was downloaded from CDEC and USGS, screened for missing and erroneous data, and processed to display daily averages and 5-day and 14-day running averages for both USGS OMR and OMR Index values. The data was then graphed in two formats, a time-series data series, and a scatter plot by water year for the years 2011 to 2017. The time-series graphs overlaid with both USGS OMR values and OMR Index values on top of one another demonstrate the completeness of the data as well as times of local bias. The scatter plots display the correlation between the two datasets for each water year.

4.2. Index Equation

The OMR Index equation as implemented for operations and in this report is as follows:

*OMR Index(cfs) = A * [Prior day flows on San Joaquin River @ Vernalis] + B * [South Delta Diversions and Exports] + C,*

with South Delta Diversions and Exports specified as follows:

*South Delta Diversions and Exports (cfs) = Clifton Court Forebay Intake + Jones Pumping Plant Exports + Total CCWD Diversions – CCWD Contra Costa Canal Diversions + (1/4 * Delta Net Channel Depletions).*

The Delta Net Channel Depletions term represents the volume of water used by local diverters in the Delta. The values are defined through the DAYFLOW program and are used in calculating the Net Delta Outflow Index.

The Coefficients A, B, C are empirically derived based on San Joaquin flows and the configuration of the Grant Line Canal (GLC) temporary barrier and the Head of Old River (HOR) barrier. For different configurations, the values of A, B, and C are given in the table that follows:

Table 1

HOR Barrier	GLC Barrier	Vernalis (cfs)	A	B	C
Out	Out	< 16,000	0.471	-0.911	83
Out	Out	16,000-28,000	0.681	-0.94	-3008
Out	Out	>28,000	0.633	-0.94	-1644
Out	In	All	0.419	-0.924	-26
In (Spring)	Out/In	All	0.079	-0.94	69
In (Fall)	Out/In	All	0.238	-0.93	-51

The dates shown for the barrier installations are from full closure (installed) to end of implementation when they are breached for the OMR Index equations. The installation schedules for GLC and HOR barriers can be obtained from the Bay-Delta website at:

Http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm

Table 2 Grant Line Canal Time Series

Water Year	Closed (Installed)	Breached (Removal)
2011	July 14, 2011	October 19, 2011
2012	May 5, 2012	October 18, 2012
2013	June 19, 2013	November 1, 2013
2014	June 3, 2014	November 4, 2014
2015	June 18, 2015	November 4, 2015
2016	April 16, 2016 (Partial)	October 28, 2016
2017	NA	Removed for 2017

Table 3 Spring Head of Old River Barrier Time Series

Water Year	Closed (Installed)	Breached (Removal)
2011	*	*
2012	April 1, 2012	June 4, 2012
2013	**	**
2014	April 8, 2014	June 9, 2014
2015	April 3, 2015	June 1, 2015
2016	April 1, 2016	June 1, 2016
2017	NA	NA

Table 4 Fall Head of Old River Barrier Time Series

Water Year	Closed (Installed)	Breached (Removal)
2014	October 1, 2014	November 11, 2014
2015	September 13, 2015	November 12, 2015
2016	September 27, 2016	November 11, 2016
2017	Removed	Removed

* The Non-Physical Barrier was planned but could not be installed due to high velocity currents in the San Joaquin River that posed excessively dangerous conditions for divers and ruled out the possibility of installing the necessary equipment on the channel bottom

** The 2013 spring Head of Old River Rock Barrier was not installed.

The Index method uses the daily inputs to the Delta, all available on CDEC, as described above along with data from the tables above to describe configuration of the HOR and GLC barriers. Depending on the configuration of the GLC and HOR barrier and amount of Vernalis flows, the OMR Index equation changes for coefficients A, B, and C according to Table 1. Five-day and 14-day running averages were then calculated from the daily OMR Index values and are presented in this report.

4.3. USGS Calculations

The USGS equation flow values for the two stations which comprise it, 11313405 (Old R. A Bacon Island CA) and 11312676 (Middle R. at Middle River CA), can be found on the USGS website at:

http://waterdata.usgs.gov/nwis/rt

The USGS OMR number is the sum of the daily tidally filtered averages of these two flow values from measured hourly values. Five-day and 14-day running averages were then calculated from the daily USGS OMR values and are presented in this report.

5. Results

The data from Water Years 2011-2017 is displayed for daily, 5-day and 14-day running averages for time series and scatter analysis in charts 1 to 42. Charts 1 to 21 display the time series data, while charts 22 to 42 display scatter analysis of USGS OMR vs OMR Index data.

Gaps in the daily time series charts show times where the OMR calculations or the averaging calculations were not possible due to missing data. There were 146 days where the 14-day average USGS OMR could not be calculated over the entire time period due to missing daily values. The 14-day average OMR Index could be calculated for every day in the time period.

As expected, the charts for 5-day and 14-day running averages are smoother for both USGS OMR and OMR Index since averaging daily OMR values over some period would inherently spread out daily fluctuations, primarily caused by the tidal cycle, over several days. The other result from smoother lines on the 5-day and 14-day average is that the absolute difference between OMR Index and USGS values is more pronounced on the daily OMR graphs.

Differences in the values for OMR are summarized in the Appendix.

The results of this analysis show a close relationship between the USGS OMR and the OMR Index from observation of time-series graphs and mathematical verification of scatter analysis graphs. Table 5, below, shows the square of the Pearson product moment correlation (R^2) coefficient from 2011 to 2017 with water year type for Sacramento Valley, and across daily, 5-day, and 14-day averages.

Table 5

Water Year	R^2 Coefficient			Sacramento Valley Water Year Index
	Daily	5-day	14-day	
2011	0.98	0.99	0.99	Wet
2012	0.91	0.96	0.98	Below Normal
2013	0.92	0.96	0.97	Dry

2014	0.90	0.95	0.97	Critical
2015	0.92	0.97	0.98	Critical
2016	0.88	0.95	0.98	Below Normal
2017	0.99	1.00	1.00	Wet

There are two conclusions that can be drawn from the table. The first is that the correlation coefficient is closer to one with longer averaging periods. That is, the 14-day average has higher coefficients than the 5-day or daily coefficients. This is expected as the longer average periods smooth out daily fluctuations in OMR flows for both methods, allowing closer tracking between the two methods since extreme swings are reduced.

The second conclusion is that for wetter year types the coefficient is also higher. In wetter years there is typically a larger distribution of OMR values, including times of significantly positive OMR values. Compared to the larger distribution of wet years, the variations in measured OMR values caused by tidal effects is small. As a result, the normal difference between the daily USGS OMR and OMR Index is comparably smaller. The coefficient is still high for critical years, so with less water the two methods still track one another closely.

6. Summary

This report shows a very close correlation between the results of the USGS OMR method and the OMR Index method with increasing correlation for longer average periods and for wetter Water Year types. The time-series graphs also show more variability in the daily USGS OMR graphs versus the Index graphs because of tidal influences and other incalculable variables that affect USGS OMR flows. The effects are more pronounced in drier years (2012-2016) with greater relative swings in daily USGS OMR flows over a tidal period. In additions, the Index OMR graphs show a more reliable data set than the USGS OMR graphs as demonstrated by the missing values in the USGS OMR.

7. Reference

MWD, 2008. A model to estimate combined Old & Middle River flows. Paul Hutton, April 2008.

OMR Flow Analysis WY2009 to WY2013: Comparison of CDEC/USGS and Hutton/MWD Index Methods. Marianne Guerin, 2014

8. Appendix

To present the maximum, average and minimum differences encountered in the USGS and Index comparison, Table 6 lists the differences between USGS and Index (USGS OMR minus OMR Index) methods for water years 2011 to 2017. The table supports the statement that longer averaging periods smooth out daily fluctuations so closer tracking between USGS OMR and Index OMR is observed. The 14 day differences are markedly smaller than the 5-day average or daily differences. The table also demonstrates a slight bias with the OMR Index to be slightly lower than the USGS OMR.

Table 6 Difference Calculation (USGS OMR – OMR Index) for each period.

	Max Difference(cfs)	Min Difference (cfs)	Average Difference (cfs)
WY 2011			
14 Day	821	-995	-84
5 Day	1421	-1395	-76
Daily	1821	-1723	-73
WY 2012			
14 Day	1089	-292	150
5 Day	1796	-607	136
Daily	3738	-1683	117
WY 2013			
14 Day	1334	-201	494
5 Day	1827	-454	493
Daily	2837	-870	491
WY 2014			
14 Day	531	-413	124
5 Day	879	-531	106
Daily	1394	-1186	90
WY 2015			
14 Day	915	-361	100
5 Day	1571	-476	170
Daily	2892	-870	185
WY 2016			
14 Day	465	-383	63
5 Day	846	-587	65
Daily	1699	-1860	42
WY 2017			
14 Day	962	-449	241
5 Day	1318	-949	242
Daily	2093	-1581	245

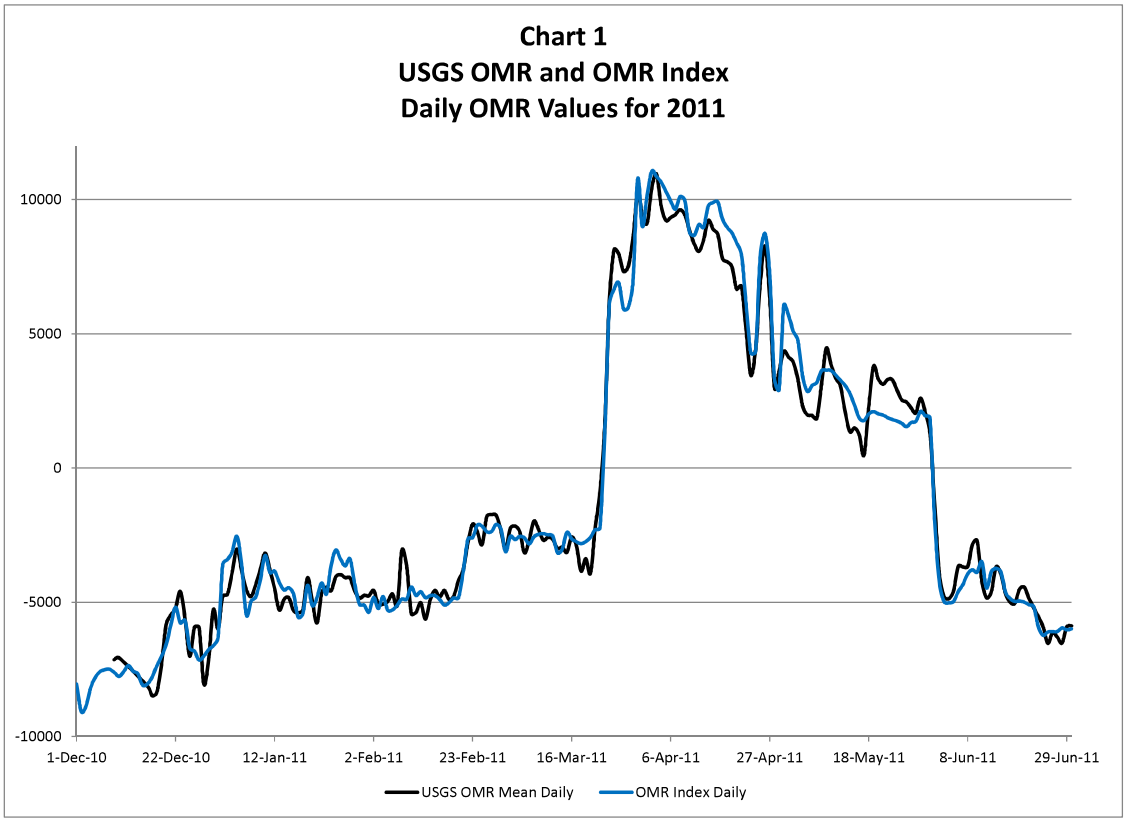
Chart 1
USGS OMR and OMR Index
Daily OMR Values for 2011
10000
5000
0
-5000
-10000
1-Dec-10
22-Dec-10
12-Jan-11
2-Feb-11
23-Feb-11
16-Mar-11
6-Apr-11
27-Apr-11
18-May-11
8-Jun-11
29-Jun-11
USGS OMR Mean Daily
OMR Index Daily

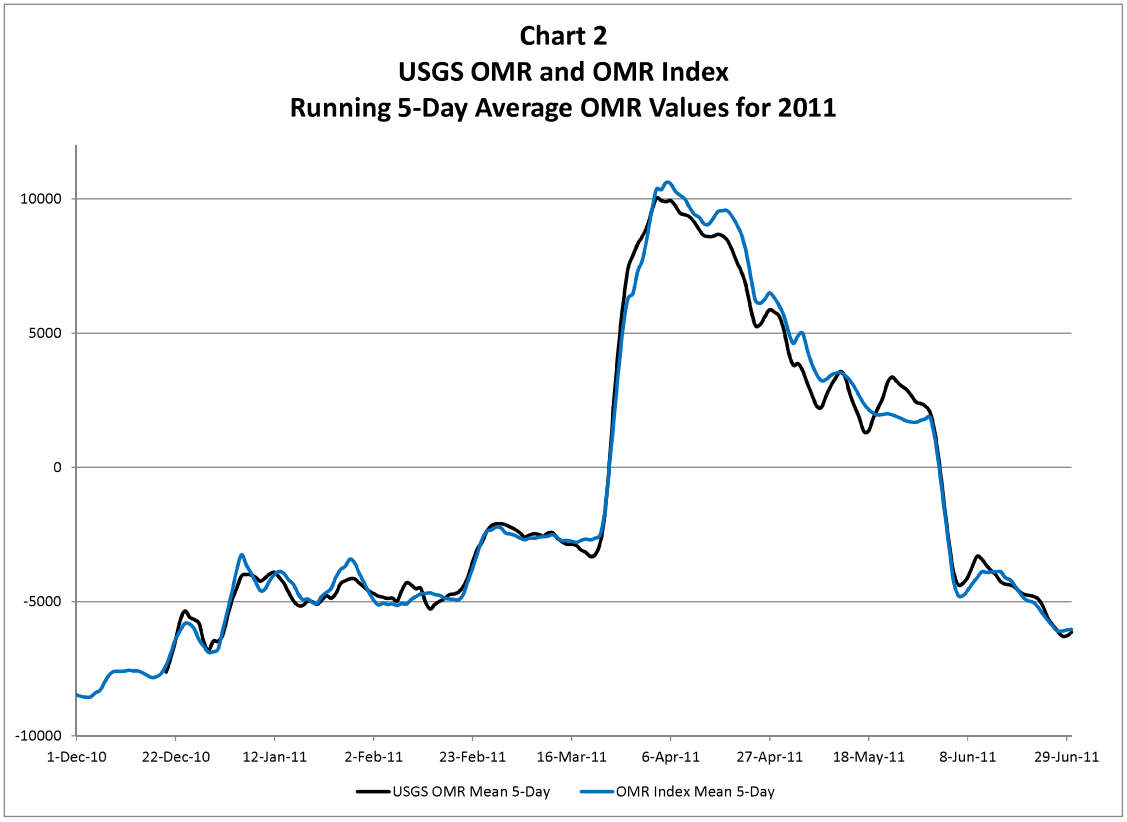
Chart 2
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2011
10000
5000
0
-5000
-10000
1-Dec-10
22-Dec-10
12-Jan-11
2-Feb-11
23-Feb-11
16-Mar-11
6-Apr-11
27-Apr-11
18-May-11
8-Jun-11
29-Jun-11
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

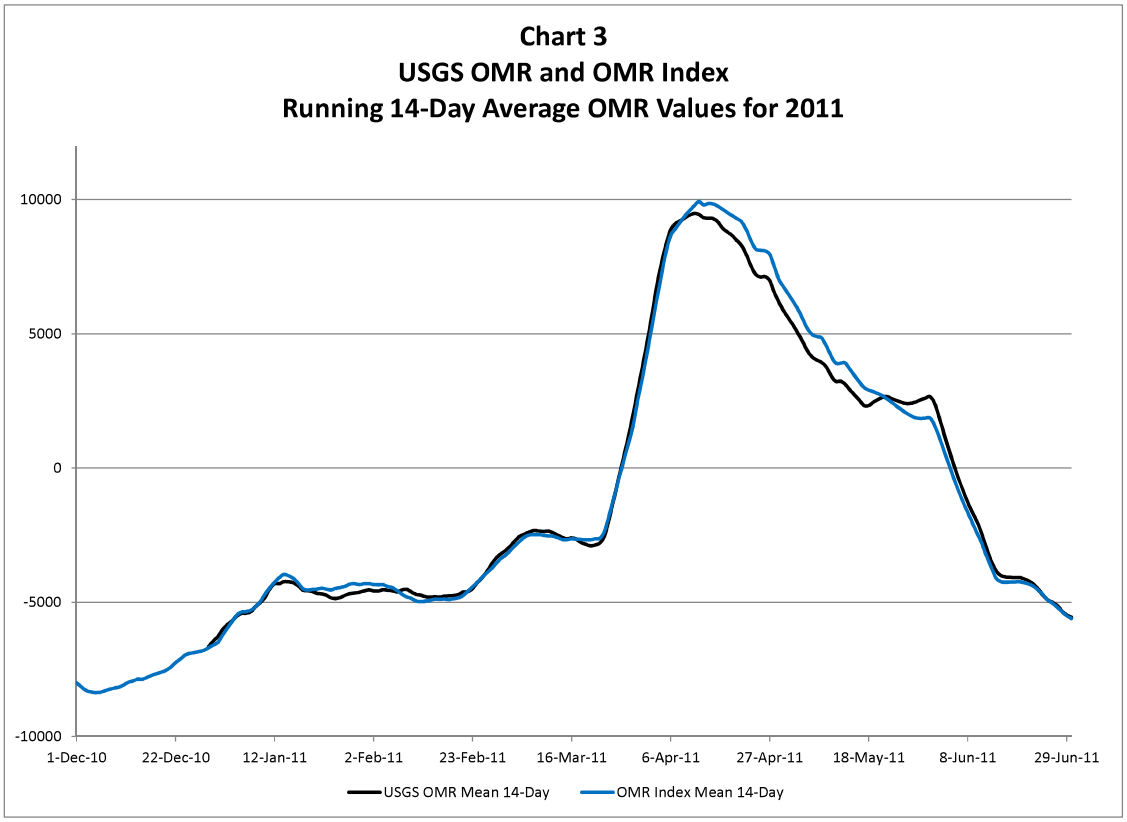
Chart 3
USGS OMR and OMR Index
Running 14-Day Average OMR Values for 2011
10000
5000
0
-5000
-10000
1-Dec-10
22-Dec-10
12-Jan-11
2-Feb-11
23-Feb-11
16-Mar-11
6-Apr-11
27-Apr-11
18-May-11
8-Jun-11
29-Jun-11
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

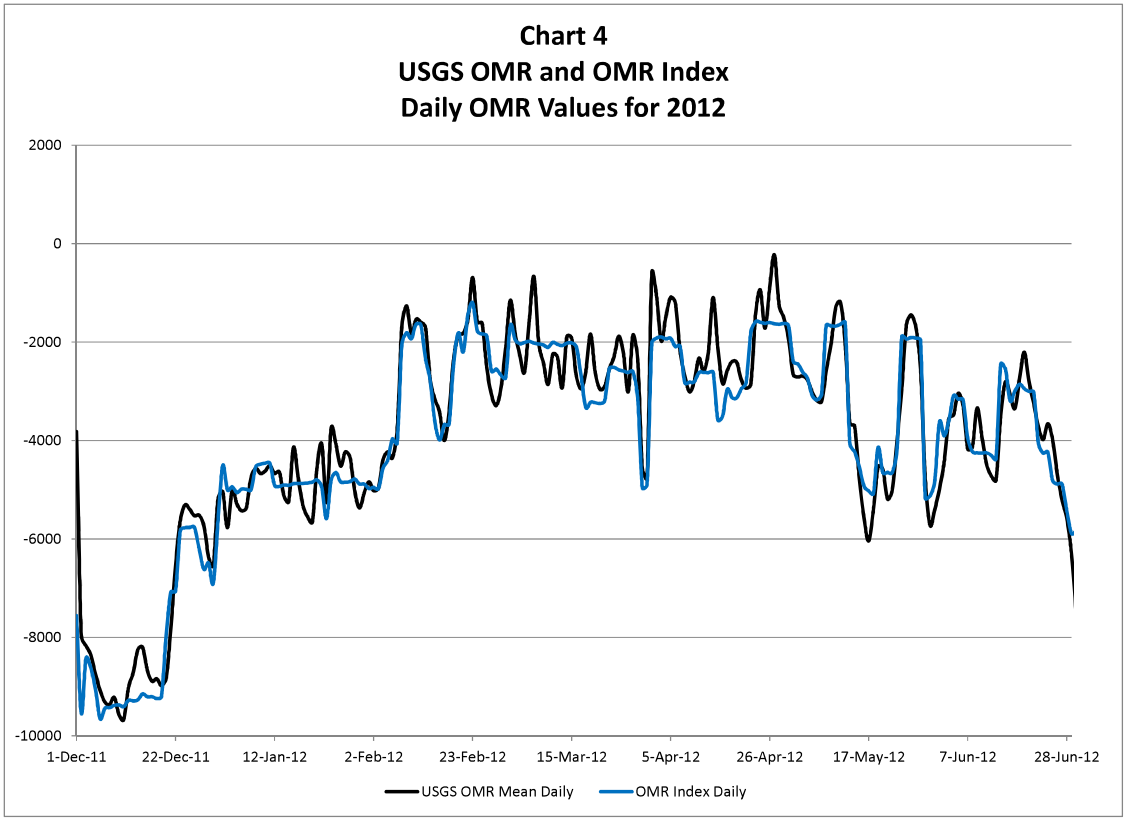
Chart 4
USGS OMR and OMR Index
Daily OMR Values for 2012
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-11
22-Dec-11
12-Jan-12
2-Feb-12
23-Feb-12
15-Mar-12
5-Apr-12
26-Apr-12
17-May-12
7-Jun-12
28-Jun-12
USGS OMR Mean Daily
OMR Index Daily

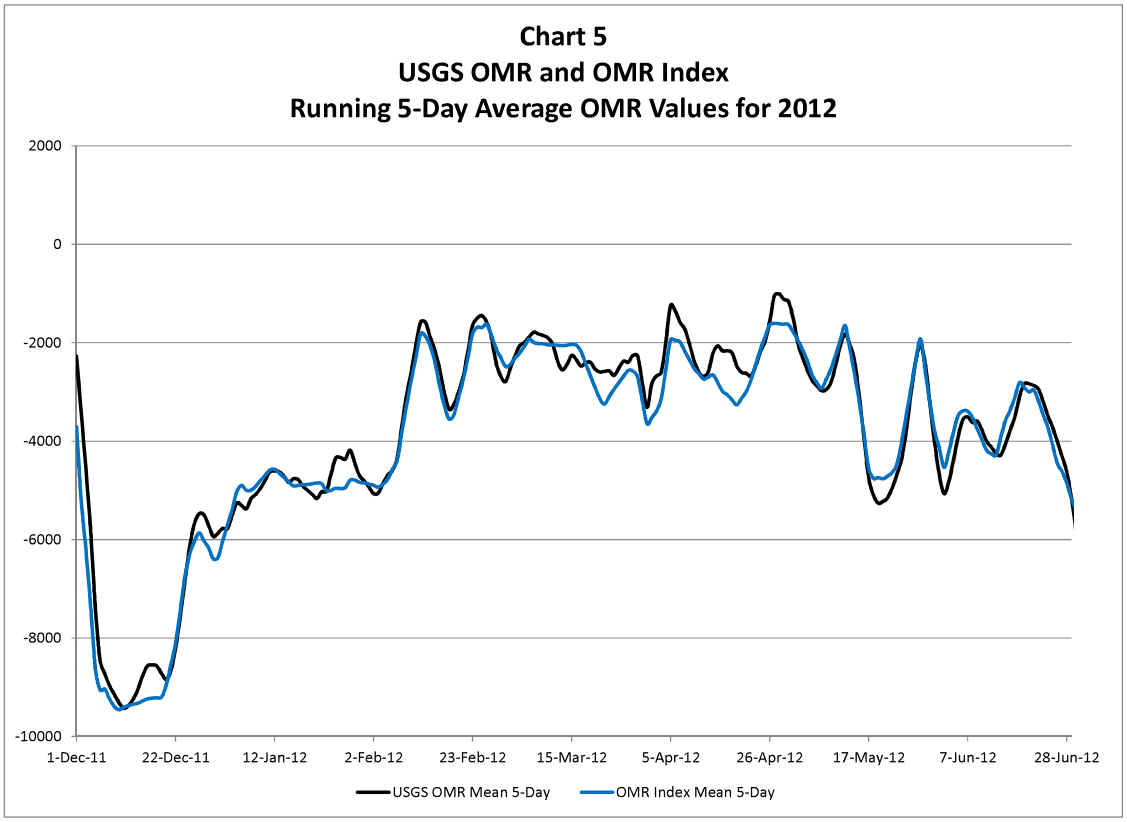
Chart 5
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2012
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-11
22-Dec-11
12-Jan-12
2-Feb-12
23-Feb-12
15-Mar-12
5-Apr-12
26-Apr-12
17-May-12
7-Jun-12
28-Jun-12
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

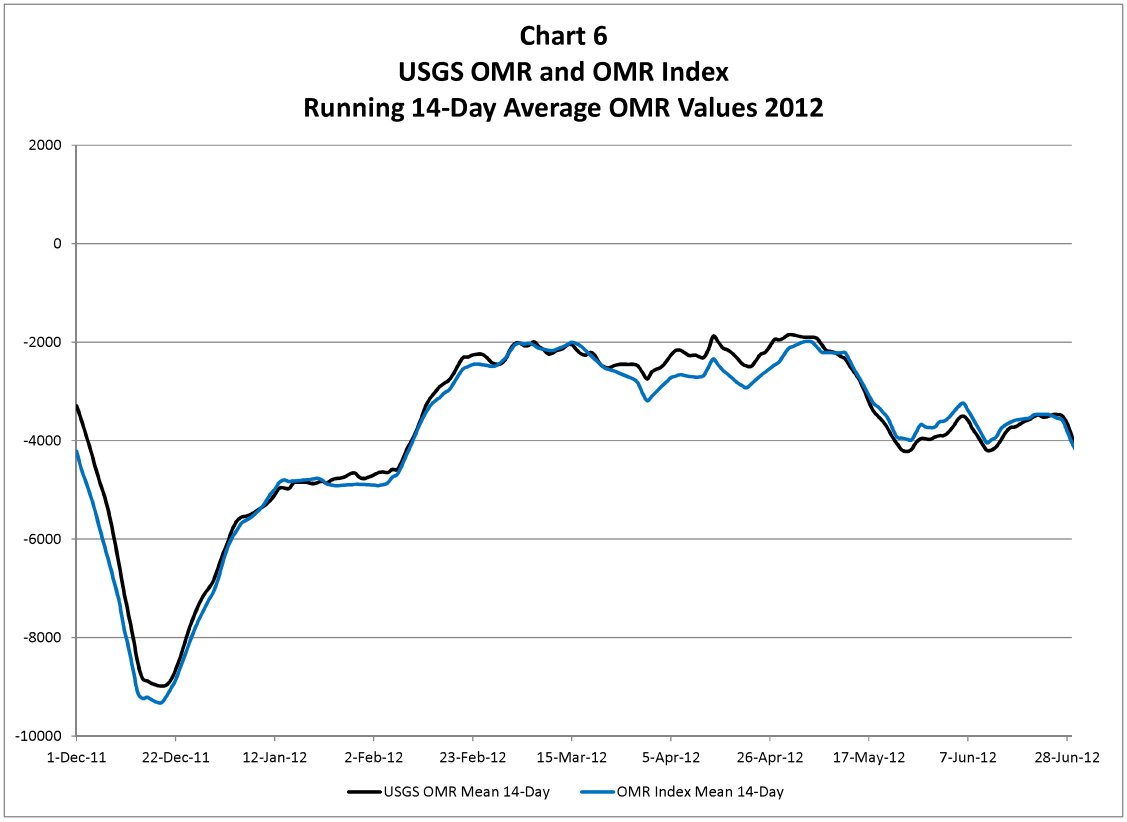
Chart 6
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2012
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-11
22-Dec-11
12-Jan-12
2-Feb-12
23-Feb-12
15-Mar-12
5-Apr-12
26-Apr-12
17-May-12
7-Jun-12
28-Jun-12
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

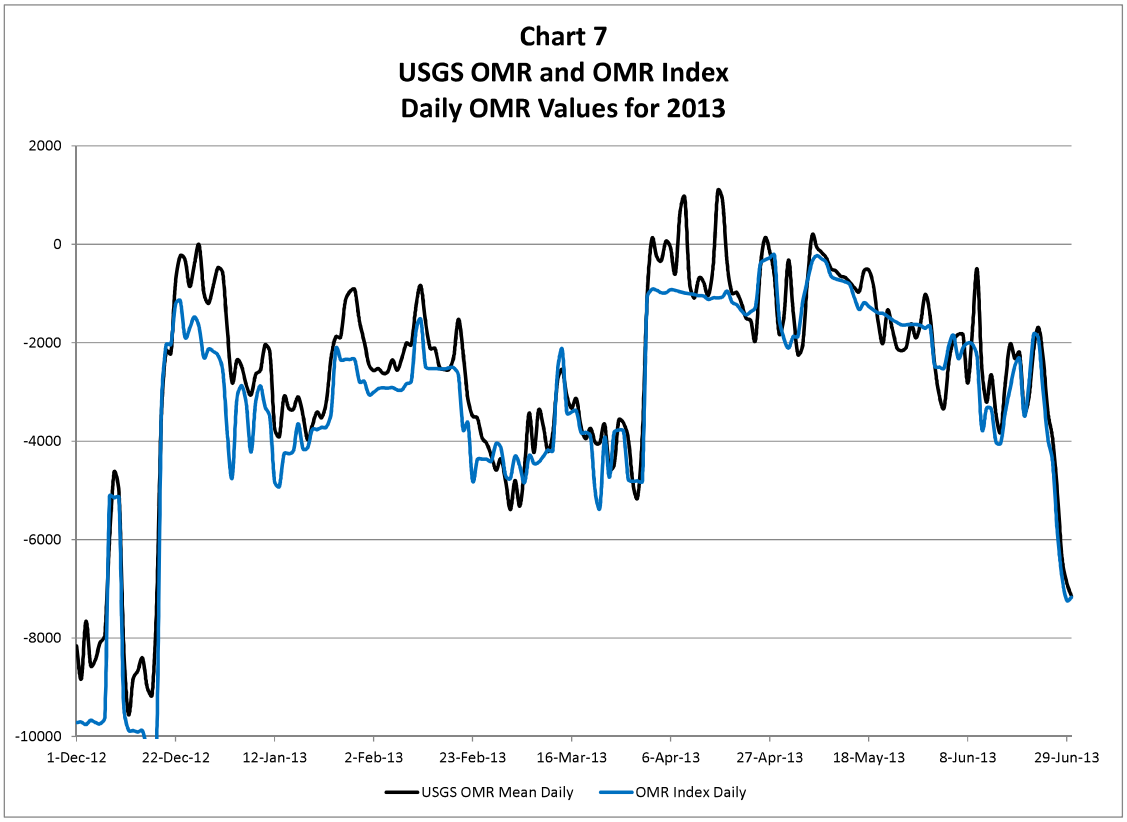
Chart 7
USGS OMR and OMR Index
Daily OMR Values for 2013
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-12
22-Dec-12
12-Jan-13
2-Feb-13
23-Feb-13
16-Mar-13
6-Apr-13
27-Apr-13
18-May-13
8-Jun-13
29-Jun-13
USGS OMR Mean Daily
OMR Index Daily

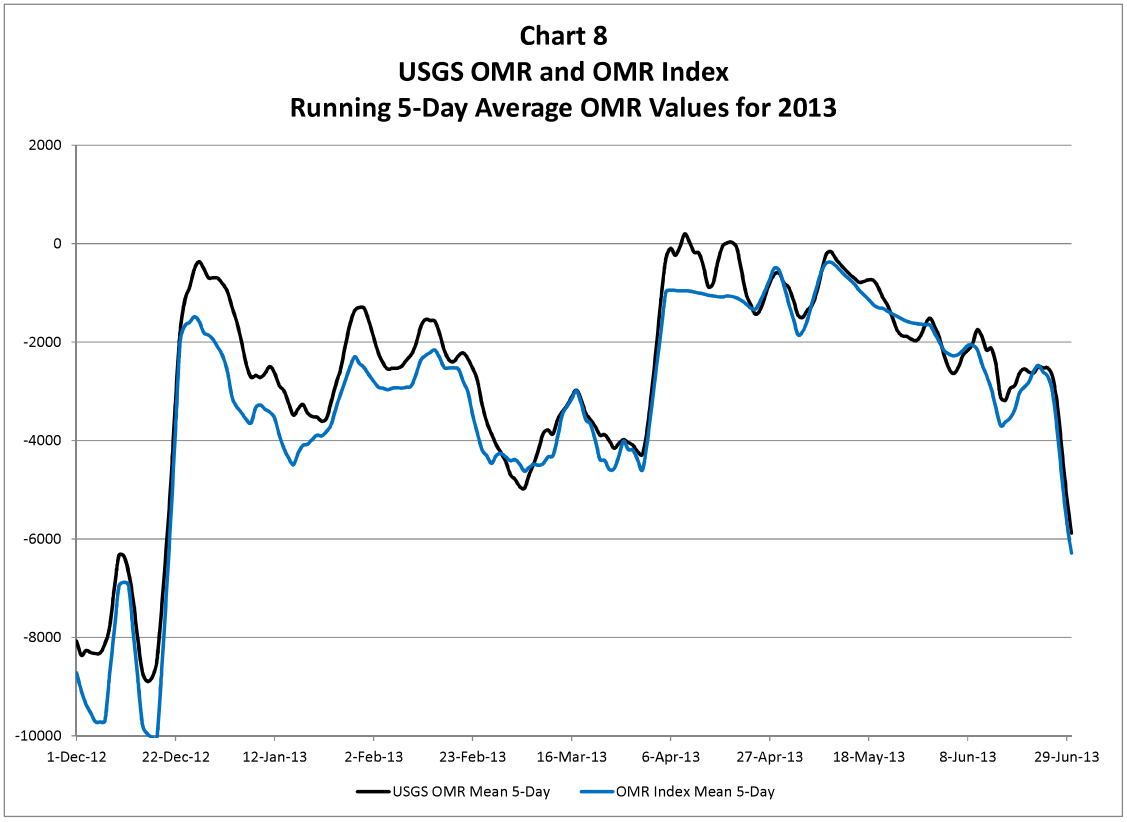
Chart 8
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2013
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-12
22-Dec-12
12-Jan-13
2-Feb-13
23-Feb-13
16-Mar-13
6-Apr-13
27-Apr-13
18-May-13
8-Jun-13
29-Jun-13
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

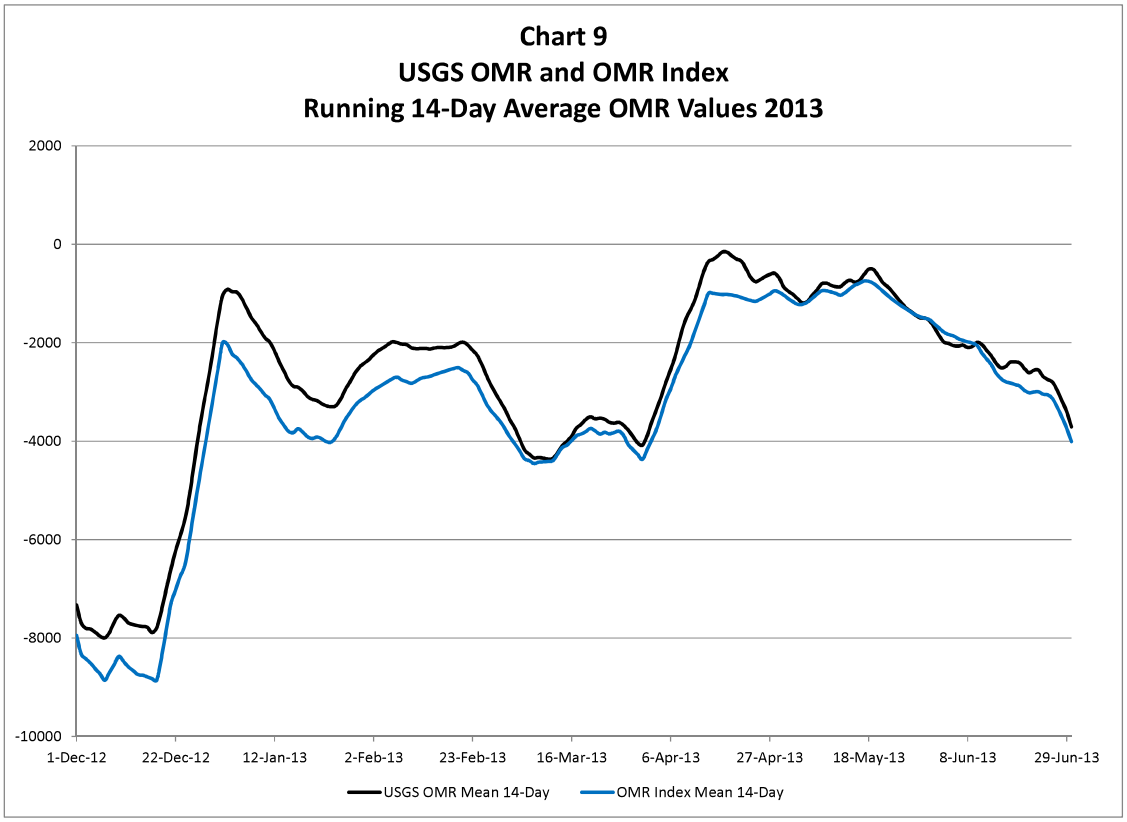
Chart 9
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2013
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-12
22-Dec-12
12-Jan-13
2-Feb-13
23-Feb-13
16-Mar-13
6-Apr-13
27-Apr-13
18-May-13
8-Jun-13
29-Jun-13
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

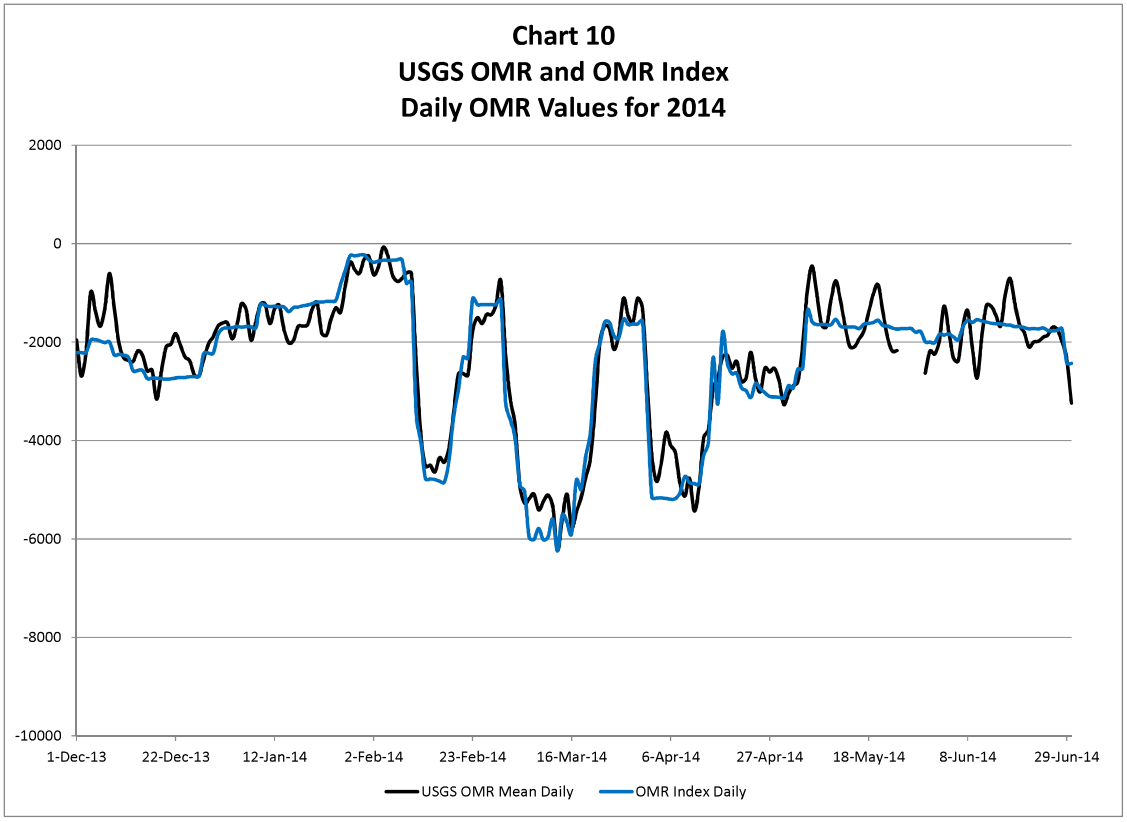
Chart 10
USGS OMR and OMR Index
Daily OMR Values for 2014
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-13
22-Dec-13
12-Jan-14
2-Feb-14
23-Feb-14
16-Mar-14
6-Apr-14
27-Apr-14
18-May-14
8-Jun-14
29-Jun-14
USGS OMR Mean Daily
OMR Index Daily

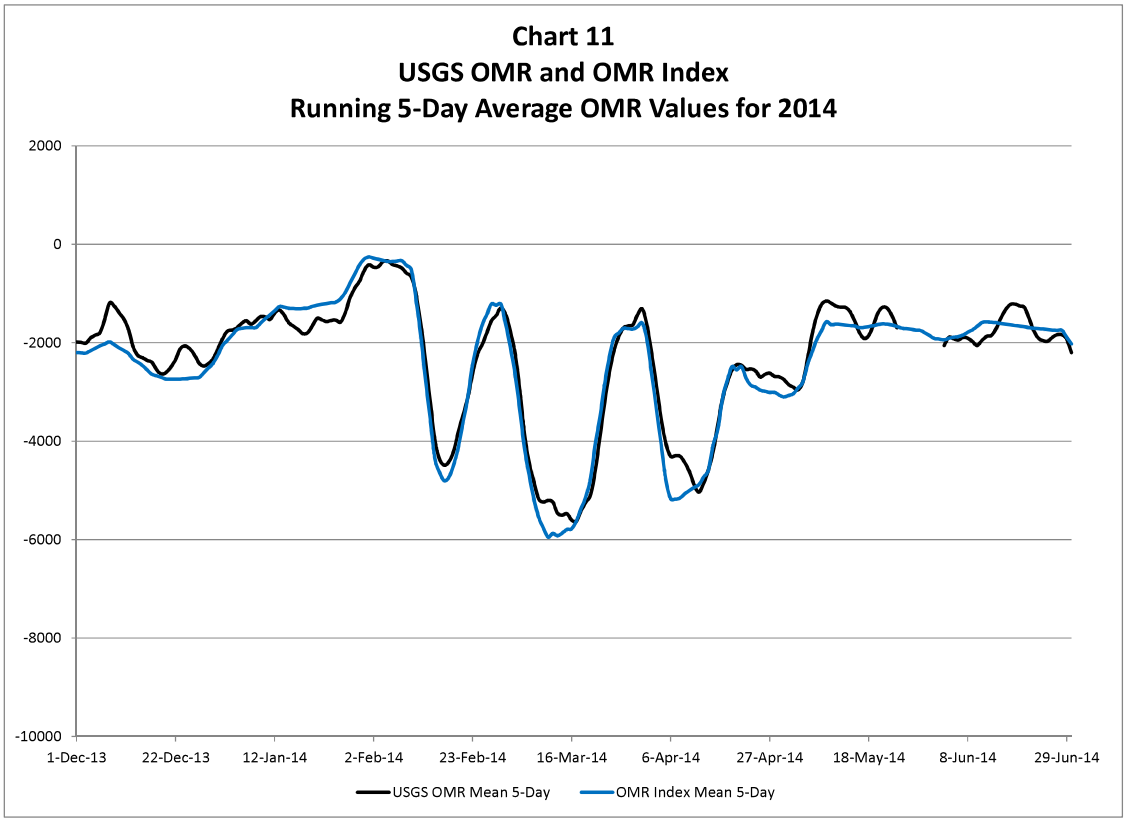
Chart 11
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2014
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-13
22-Dec-13
12-Jan-14
2-Feb-14
23-Feb-14
16-Mar-14
6-Apr-14
27-Apr-14
18-May-14
8-Jun-14
29-Jun-14
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

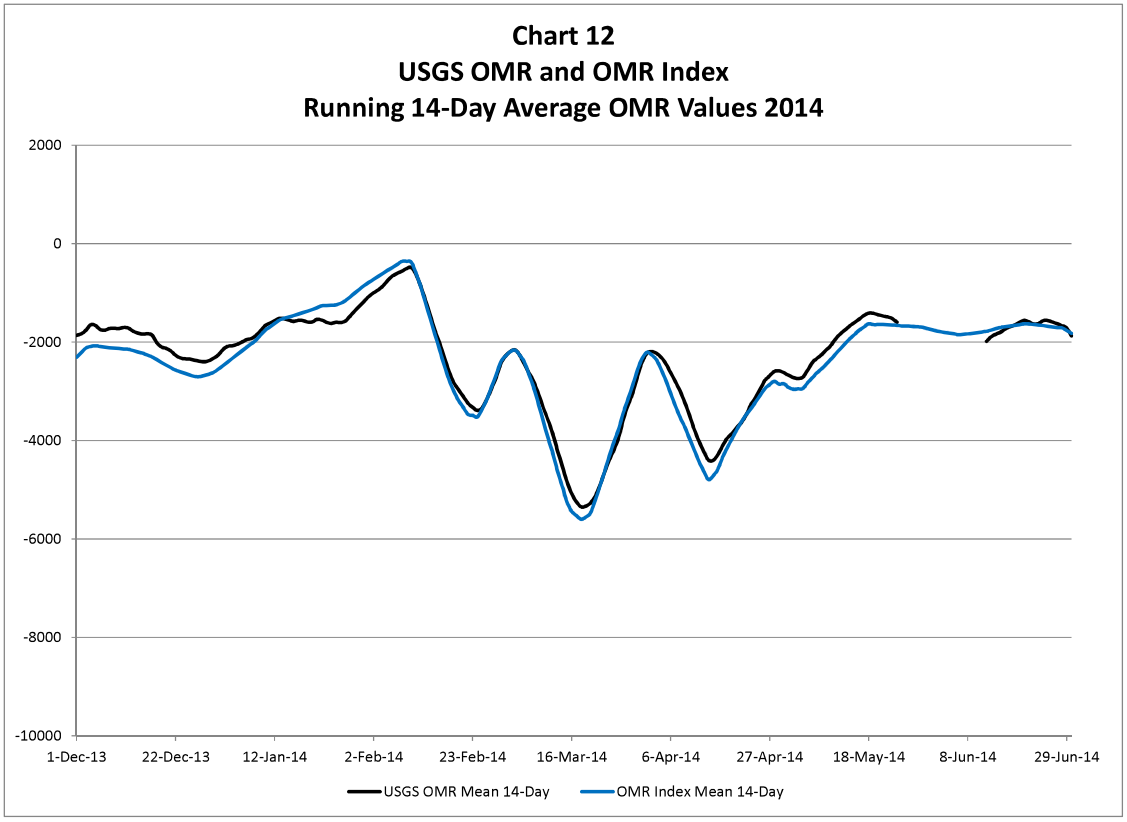
Chart 12
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2014
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-13
22-Dec-13
12-Jan-14
2-Feb-14
23-Feb-14
16-Mar-14
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18-May-14
8-Jun-14
29-Jun-14
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

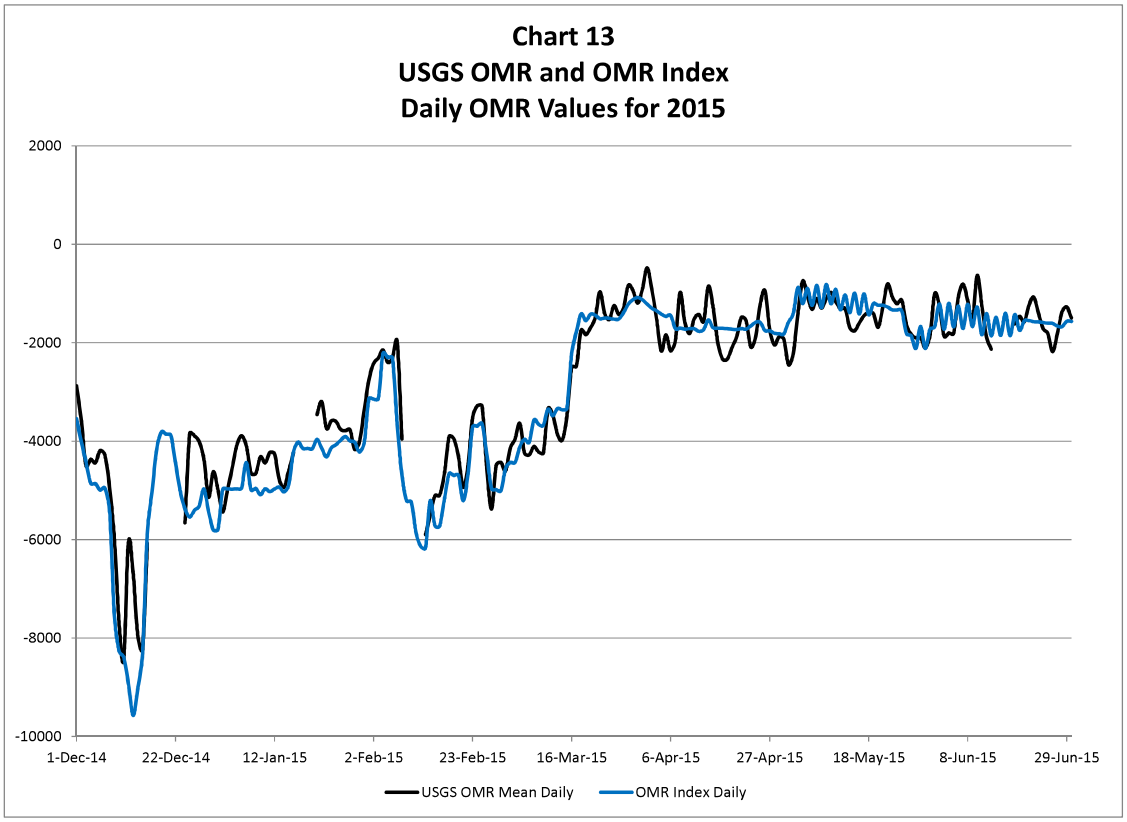
Chart 13
USGS OMR and OMR Index
Daily OMR Values for 2015
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-14
22-Dec-14
12-Jan-15
2-Feb-15
23-Feb-15
16-Mar-15
6-Apr-15
27-Apr-15
18-May-15
8-Jun-15
29-Jun-15
USGS OMR Mean Daily
OMR Index Daily

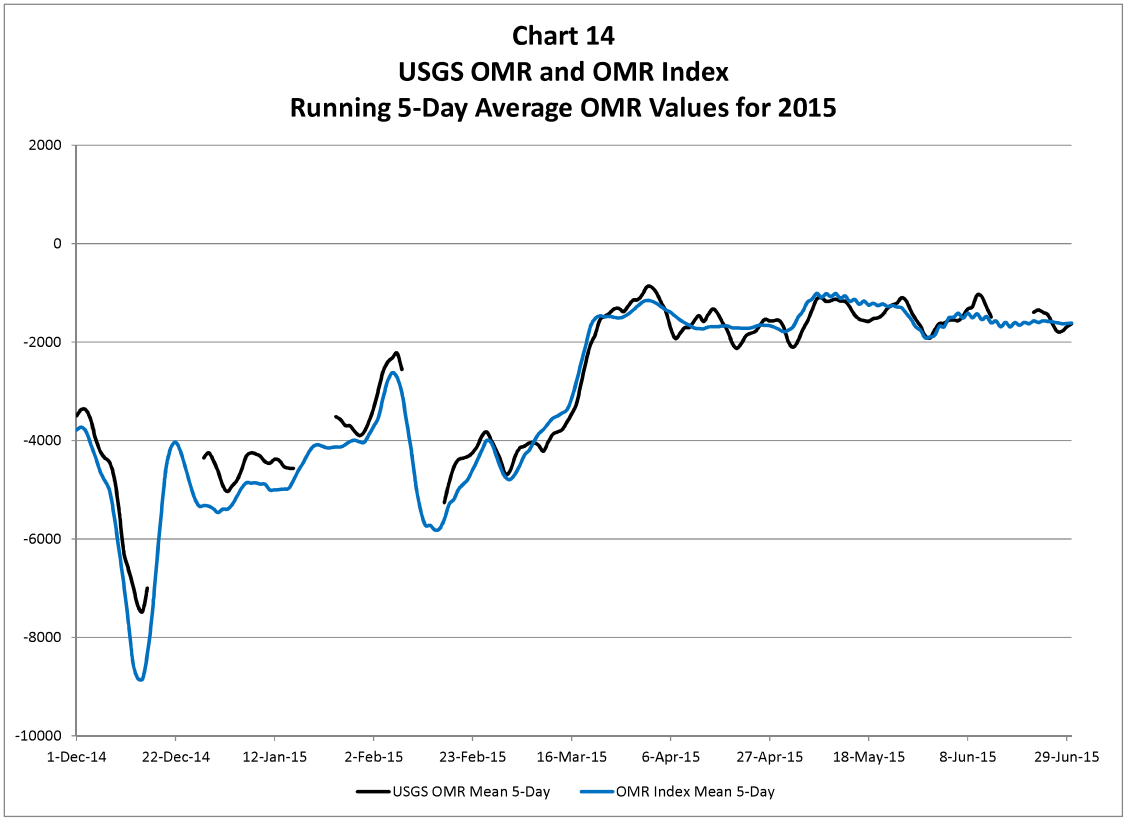
Chart 14
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2015
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-14
22-Dec-14
12-Jan-15
2-Feb-15
23-Feb-15
16-Mar-15
6-Apr-15
27-Apr-15
18-May-15
8-Jun-15
29-Jun-15
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

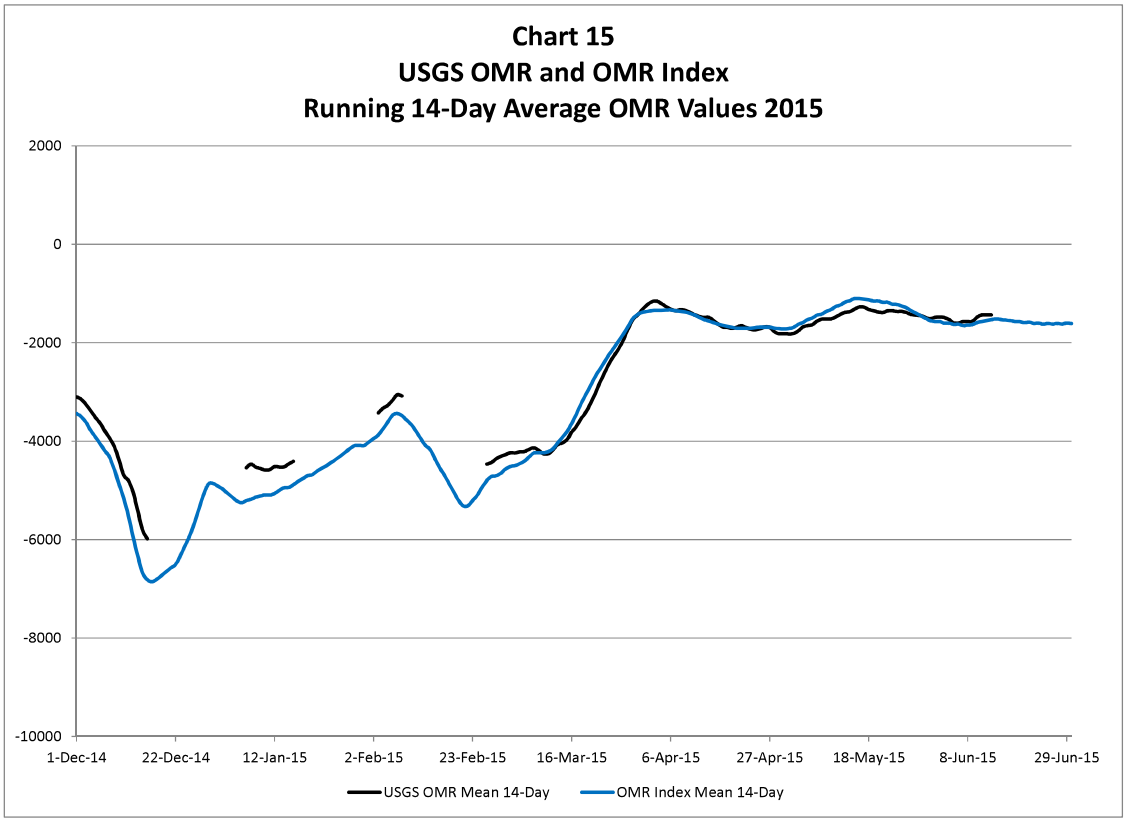
Chart 15
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2015
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-14
22-Dec-14
12-Jan-15
2-Feb-15
23-Feb-15
16-Mar-15
6-Apr-15
27-Apr-15
18-May-15
8-Jun-15
29-Jun-15
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

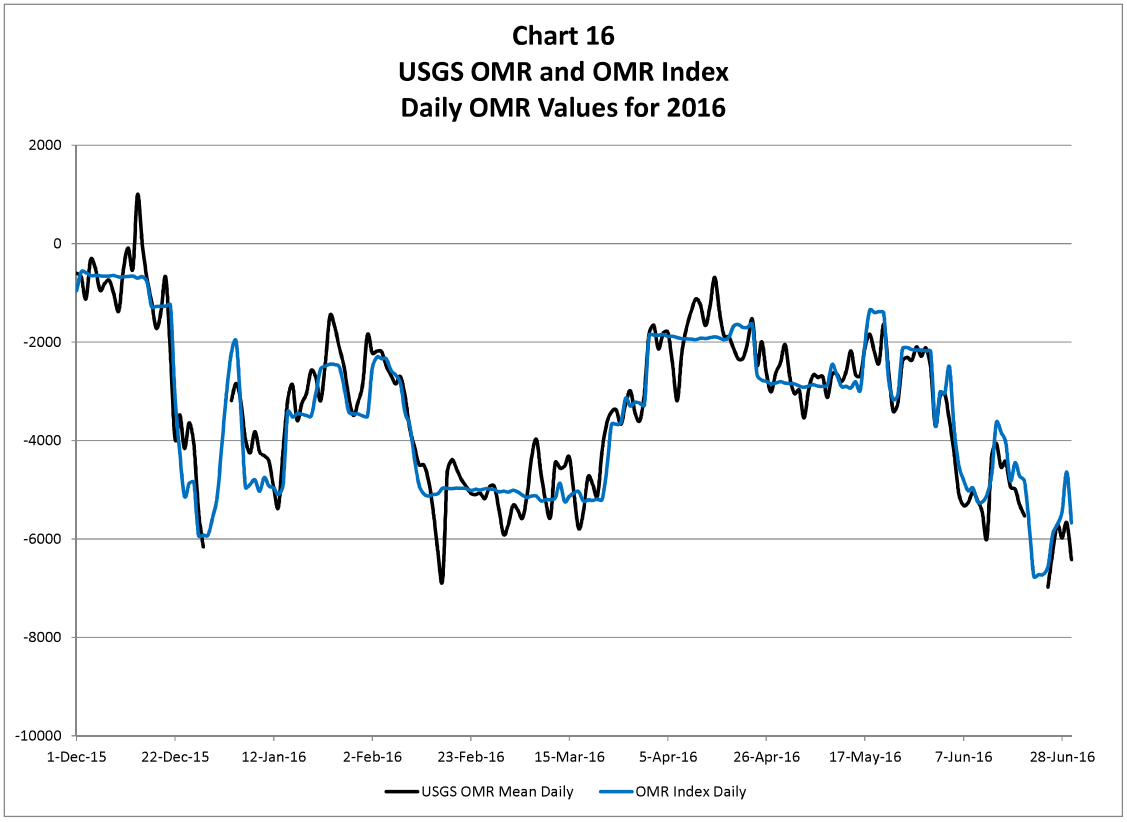
Chart 16
USGS OMR and OMR Index
Daily OMR Values for 2016
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-15
22-Dec-15
12-Jan-16
2-Feb-16
23-Feb-16
15-Mar-16
5-Apr-16
26-Apr-16
17-May-16
7-Jun-16
28-Jun-16
USGS OMR Mean Daily
OMR Index Daily

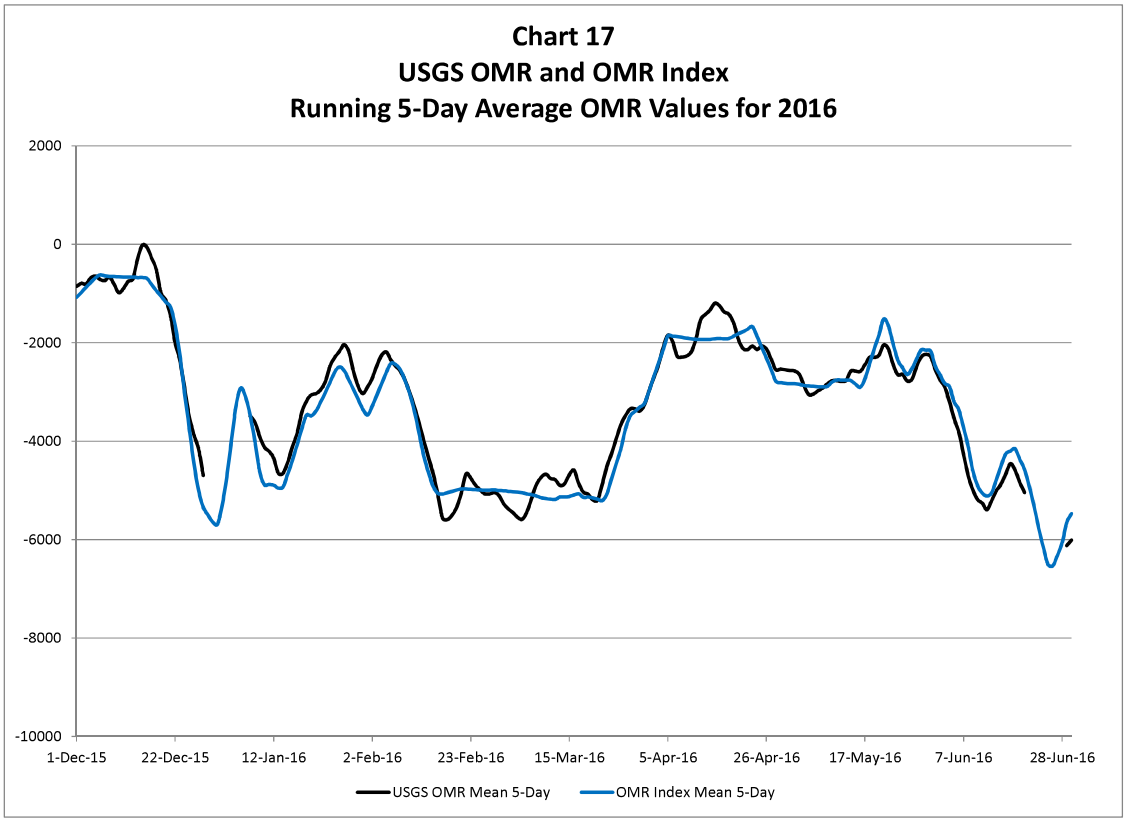
Chart 17
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2016
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-15
22-Dec-15
12-Jan-16
2-Feb-16
23-Feb-16
15-Mar-16
5-Apr-16
26-Apr-16
17-May-16
7-Jun-16
28-Jun-16
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

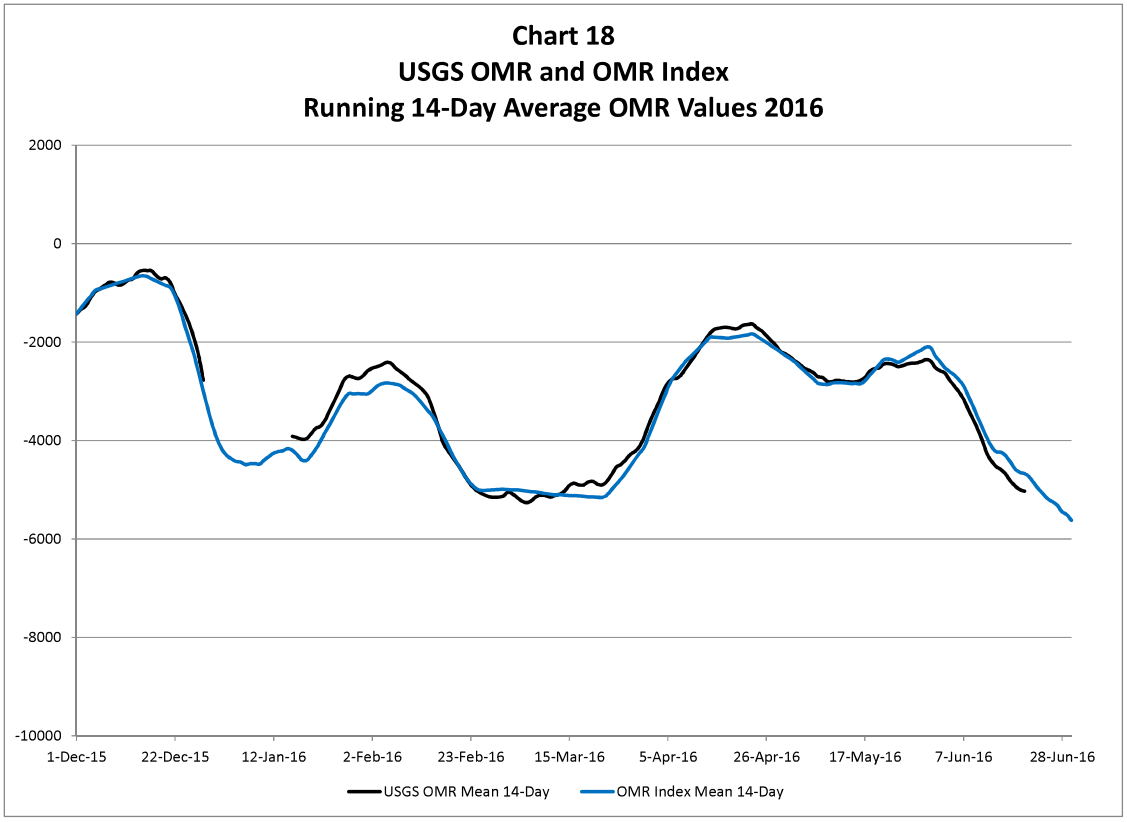
Chart 18
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2016
2000
0
-2000
-4000
-6000
-8000
-10000
1-Dec-15
22-Dec-15
12-Jan-16
2-Feb-16
23-Feb-16
15-Mar-16
5-Apr-16
26-Apr-16
17-May-16
7-Jun-16
28-Jun-16
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

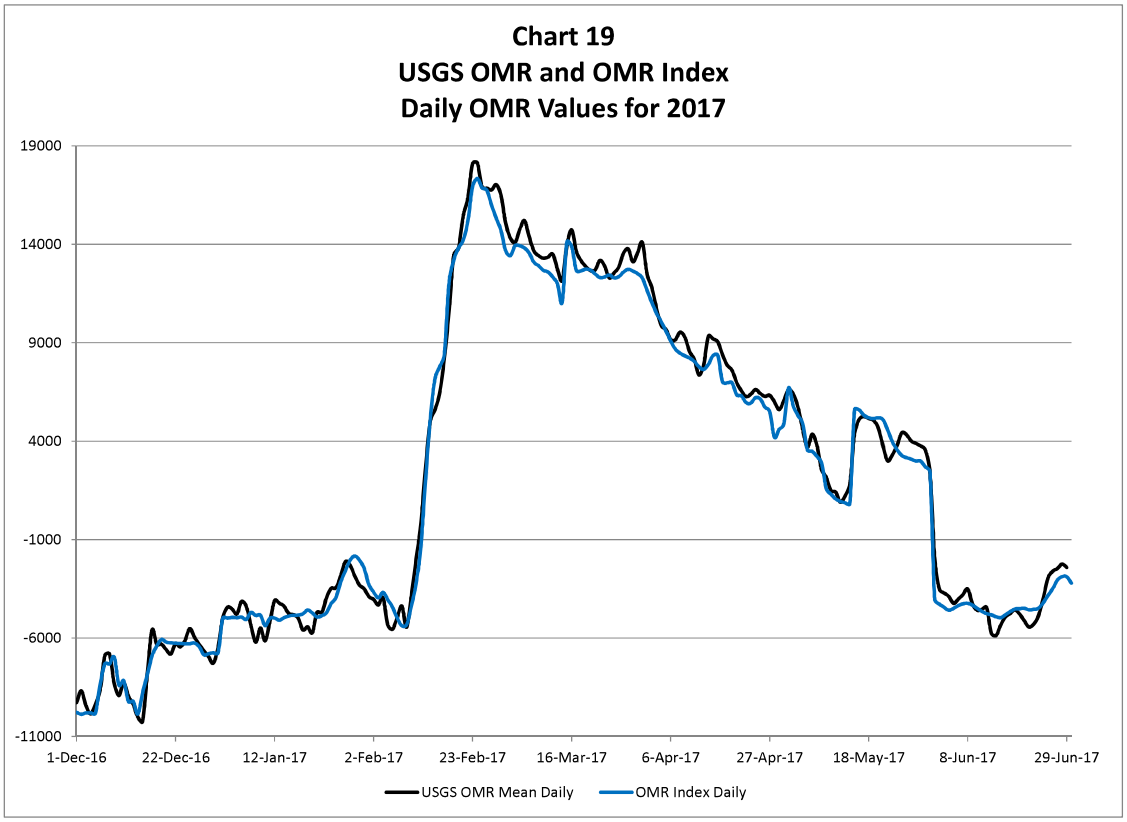
Chart 19
USGS OMR and OMR Index
Daily OMR Values for 2017
19000
14000
9000
4000
-1000
-6000
-11000
1-Dec-16
22-Dec-16
12-Jan-17
2-Feb-17
23-Feb-17
16-Mar-17
6-Apr-17
27-Apr-17
18-May-17
8-Jun-17
29-Jun-17
USGS OMR Mean Daily
OMR Index Daily

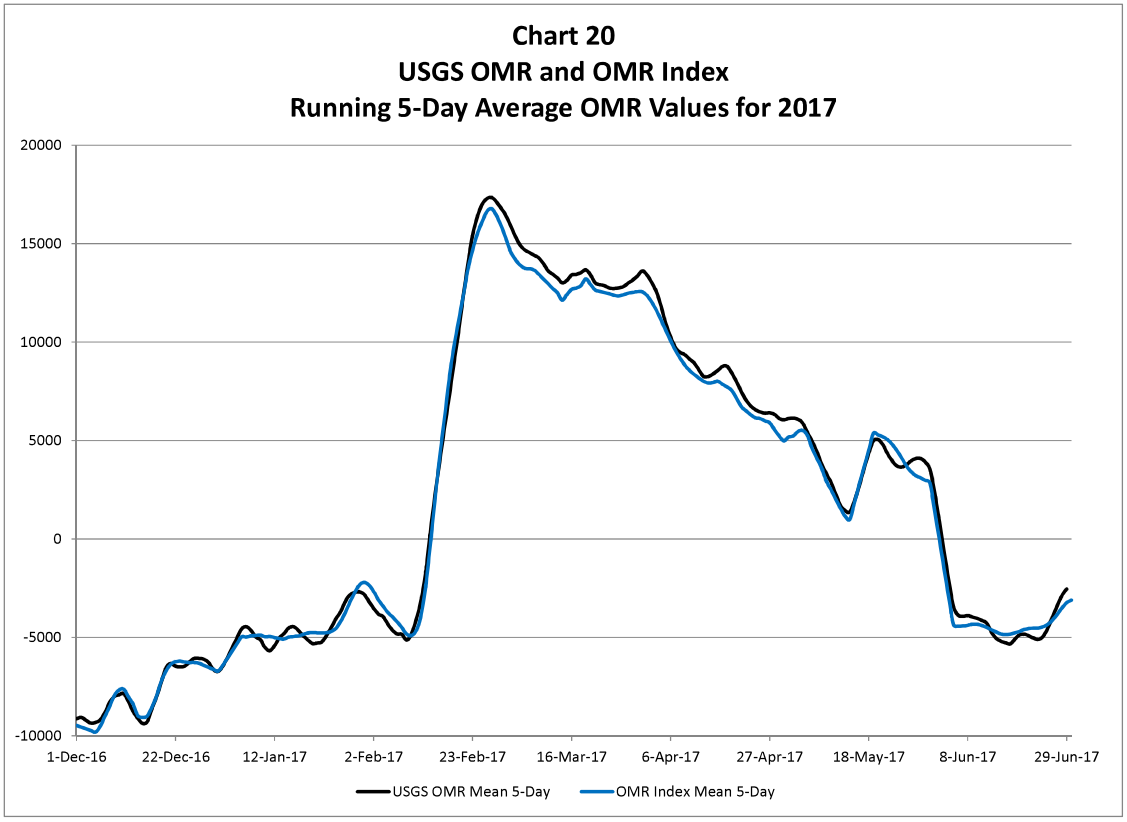
Chart 20
USGS OMR and OMR Index
Running 5-Day Average OMR Values for 2017
20000
15000
10000
5000
0
-5000
-10000
1-Dec-16
22-Dec-16
12-Jan-17
2-Feb-17
23-Feb-17
16-Mar-17
6-Apr-17
27-Apr-17
18-May-17
8-Jun-17
29-Jun-17
USGS OMR Mean 5-Day
OMR Index Mean 5-Day

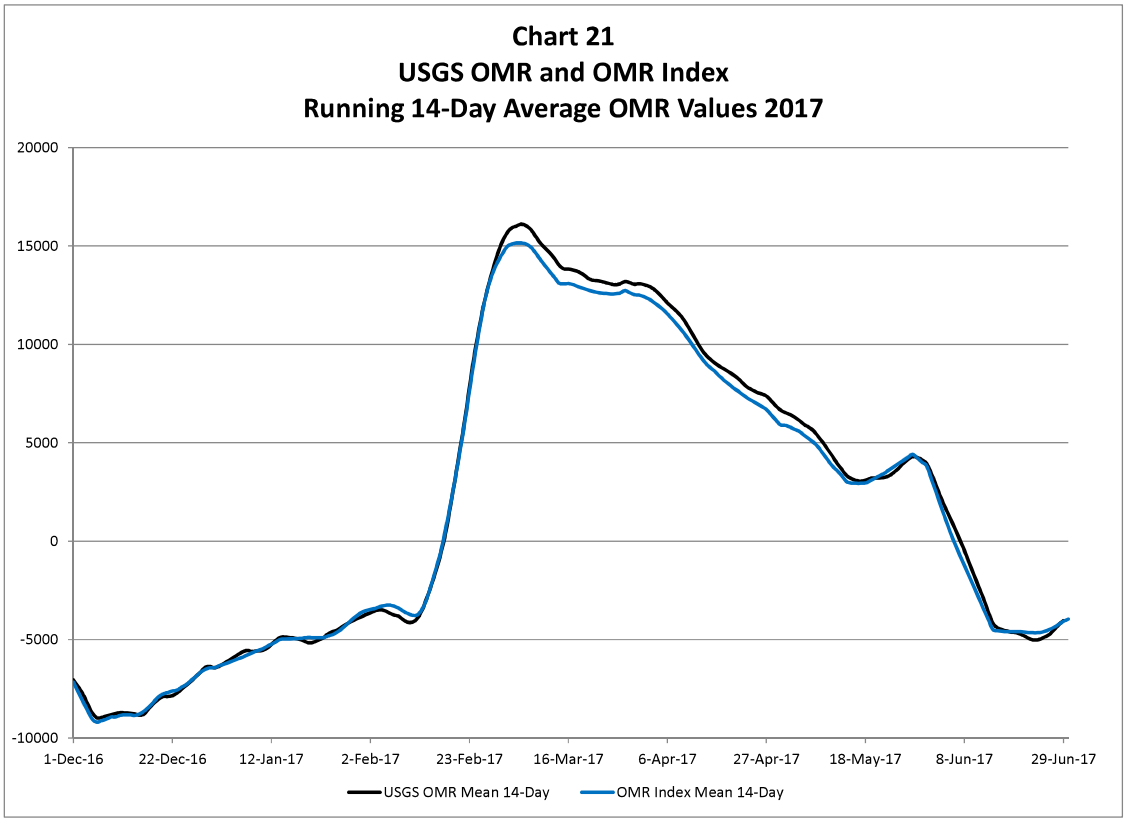
Chart 21
USGS OMR and OMR Index
Running 14-Day Average OMR Values 2017
20000
15000
10000
5000
0
-5000
-10000
1-Dec-16
22-Dec-16
12-Jan-17
2-Feb-17
23-Feb-17
16-Mar-17
6-Apr-17
27-Apr-17
18-May-17
8-Jun-17
29-Jun-17
USGS OMR Mean 14-Day
OMR Index Mean 14-Day

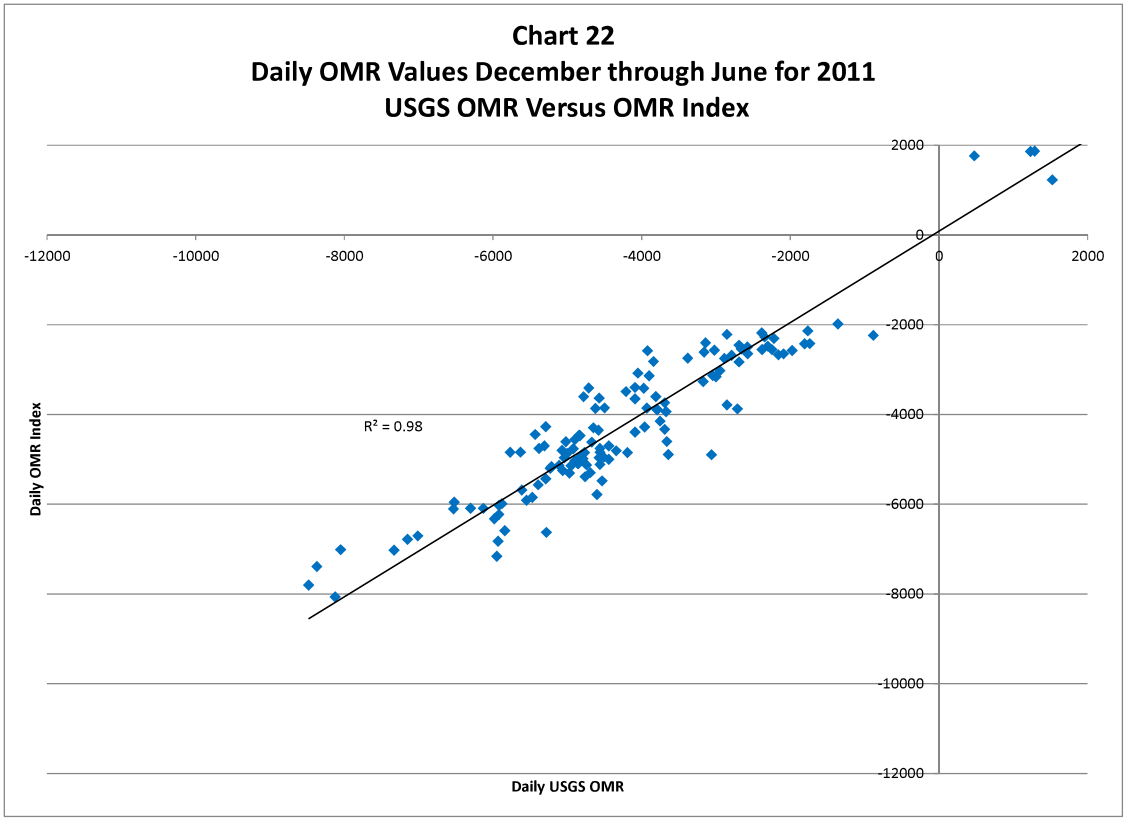
Chart 22
Daily OMR Values December through June for 2011
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
R² = 0.98
Daily OMR Index
Daily USGS OMR

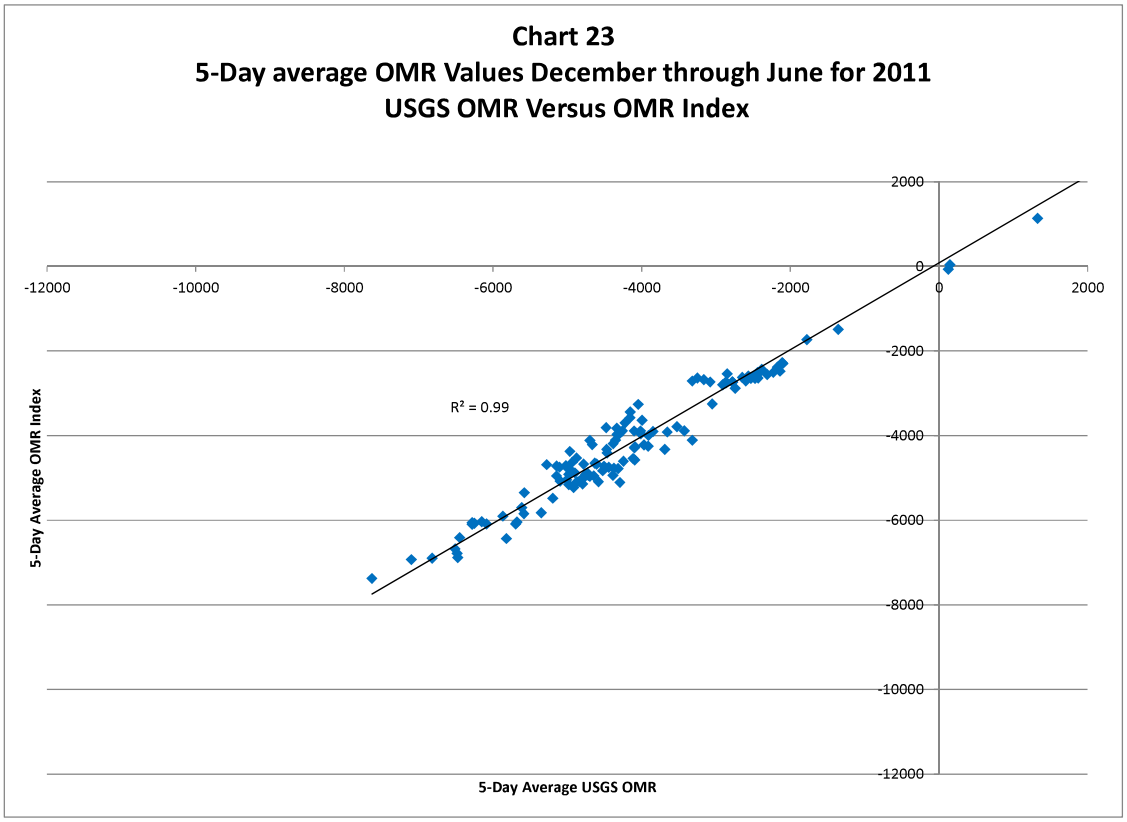
Chart 23
5-Day average OMR Values December through June for 2011
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
R² = 0.99
5-Day Average OMR Index
5-Day Average USGS OMR

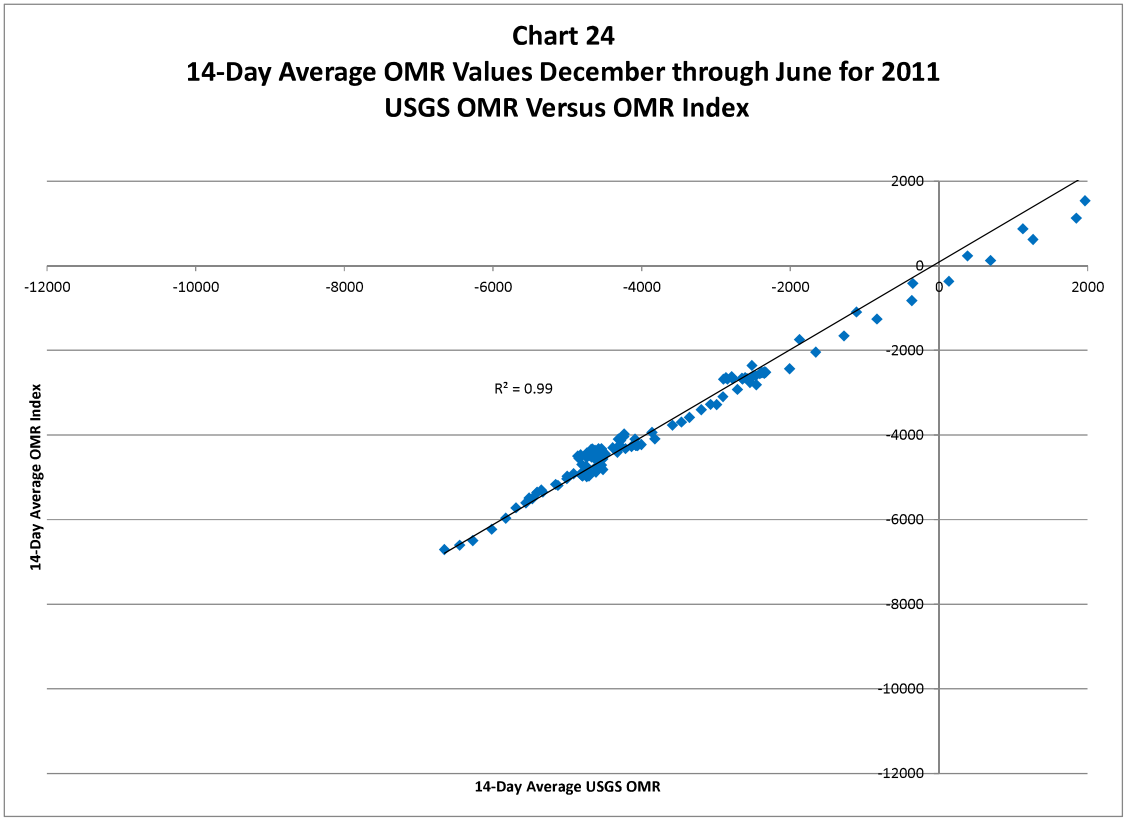
Chart 24
14-Day Average OMR Values December through June for 2011
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
R² = 0.99
14-Day Average OMR Index
14-Day Average USGS OMR

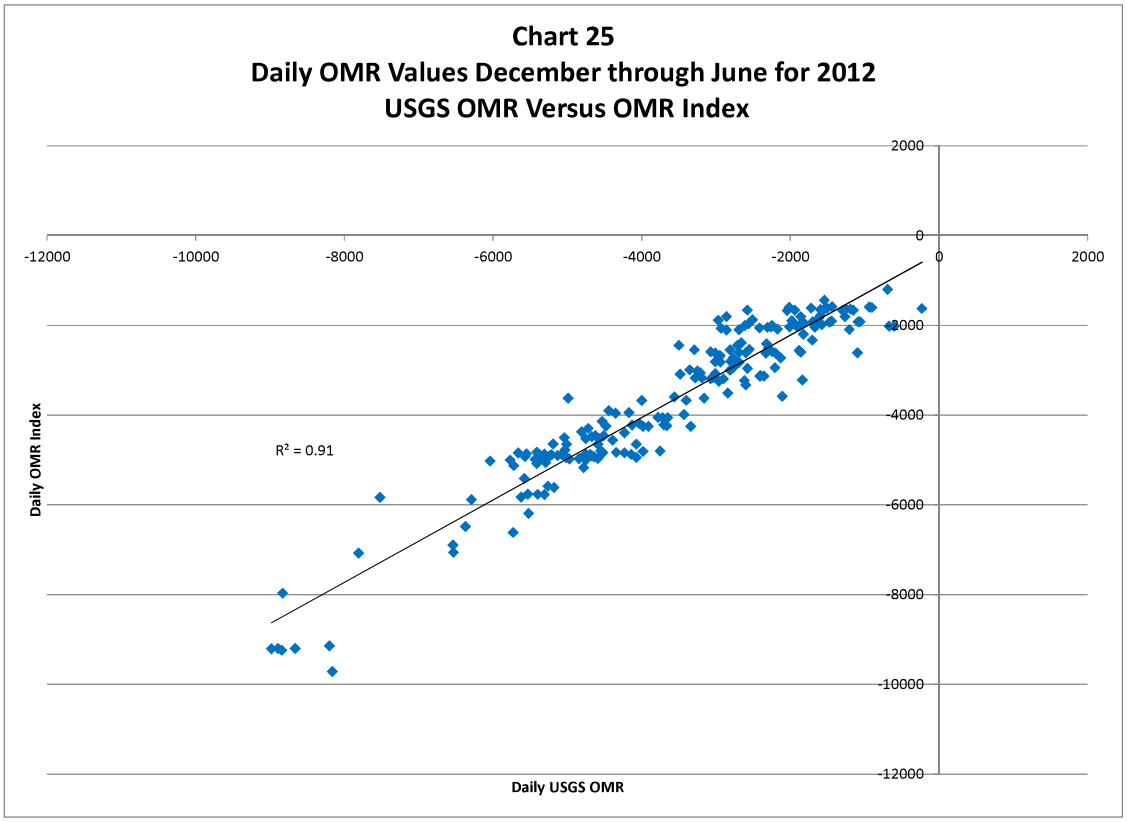
Chart 25
Daily OMR Values December through June for 2012
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
Daily OMR Index
R² = 0.91
Daily USGS OMR

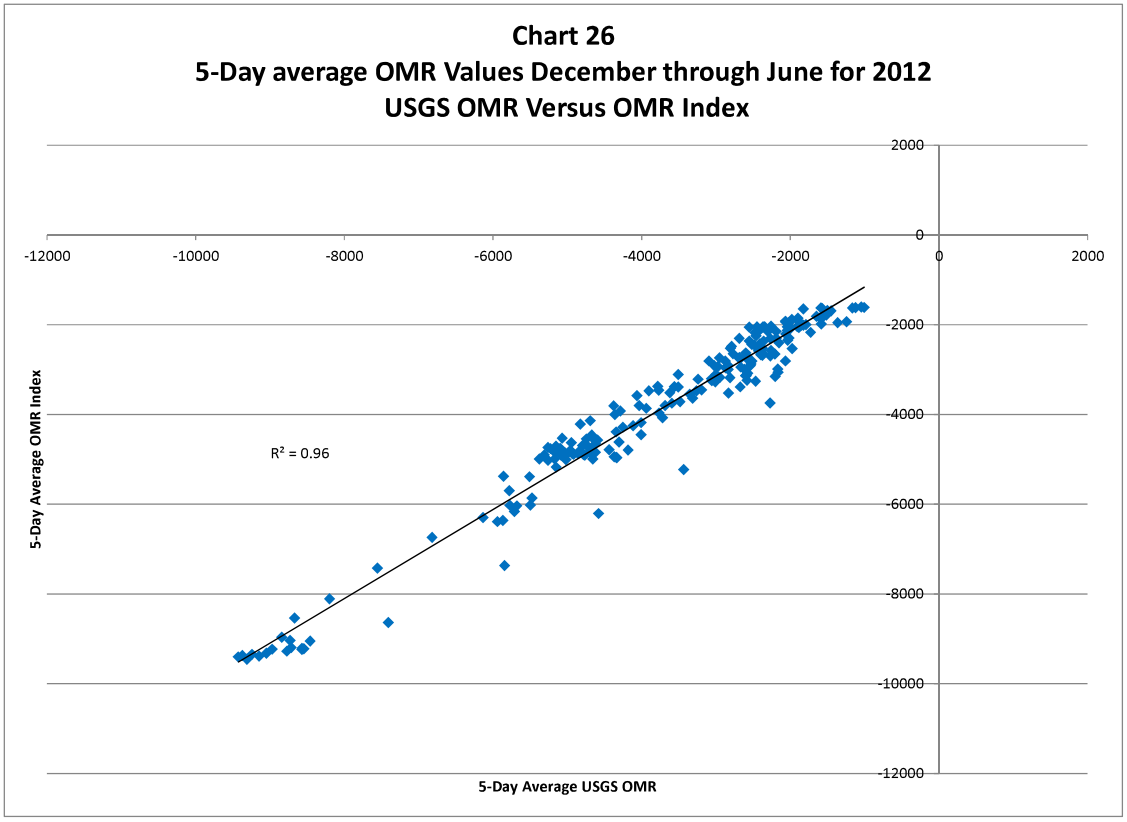
Chart 26
5-Day average OMR Values December through June for 2012
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
5-Day Average OMR Index
R² = 0.96
5-Day Average USGS OMR

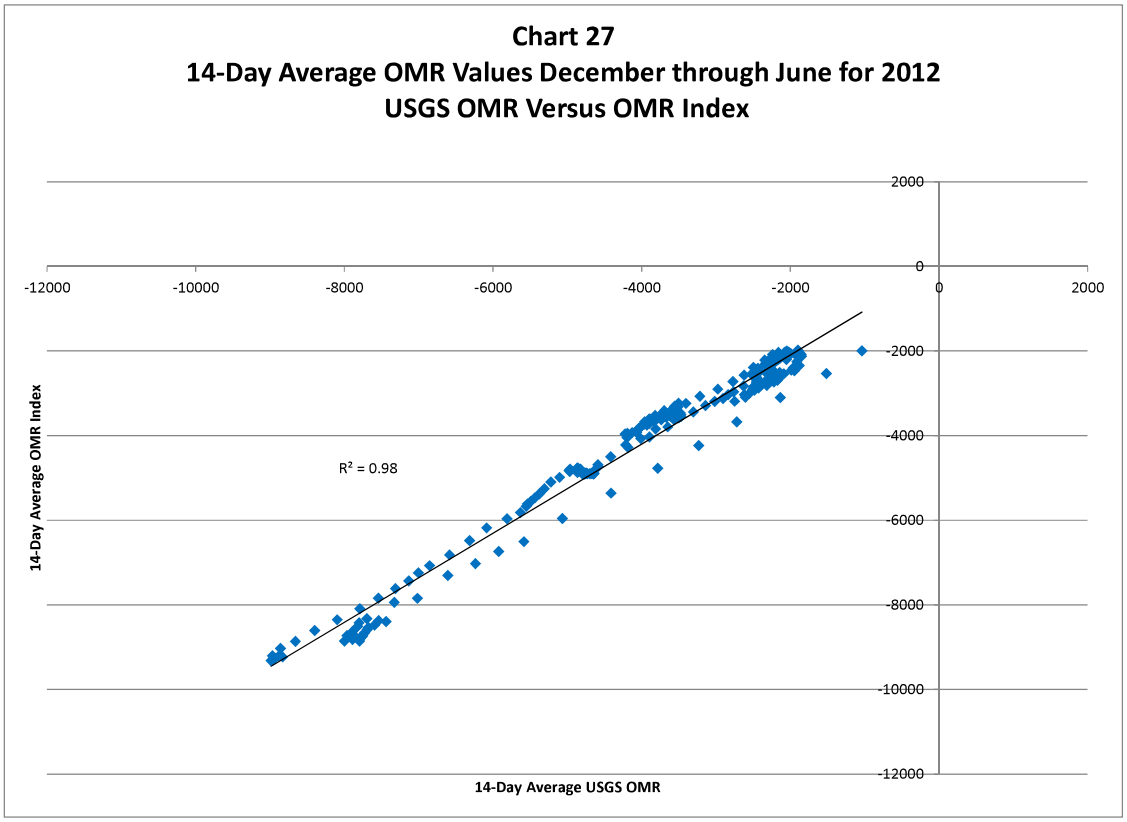
Chart 27
14-Day Average OMR Values December through June for 2012
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
14-Day Average OMR Index
R² = 0.98
14-Day Average USGS OMR

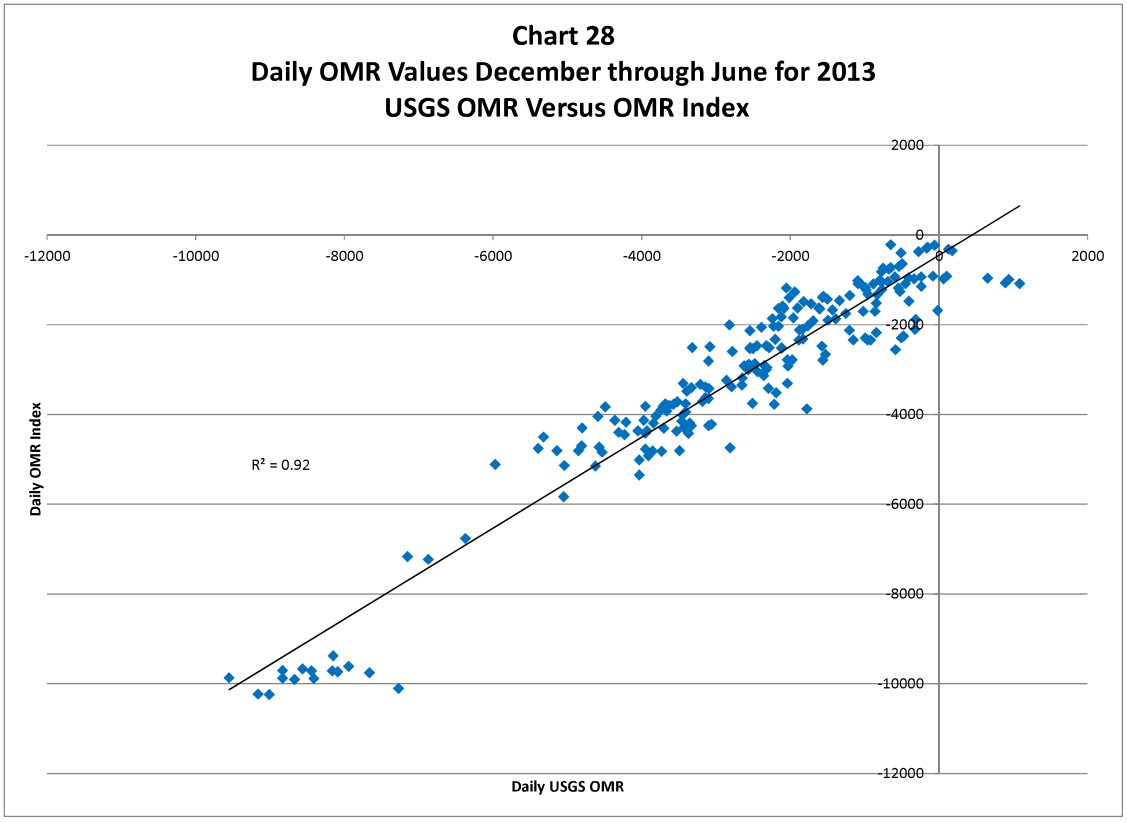
Chart 28
Daily OMR Values December through June for 2013
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
Daily OMR Index
R² = 0.92
Daily USGS OMR

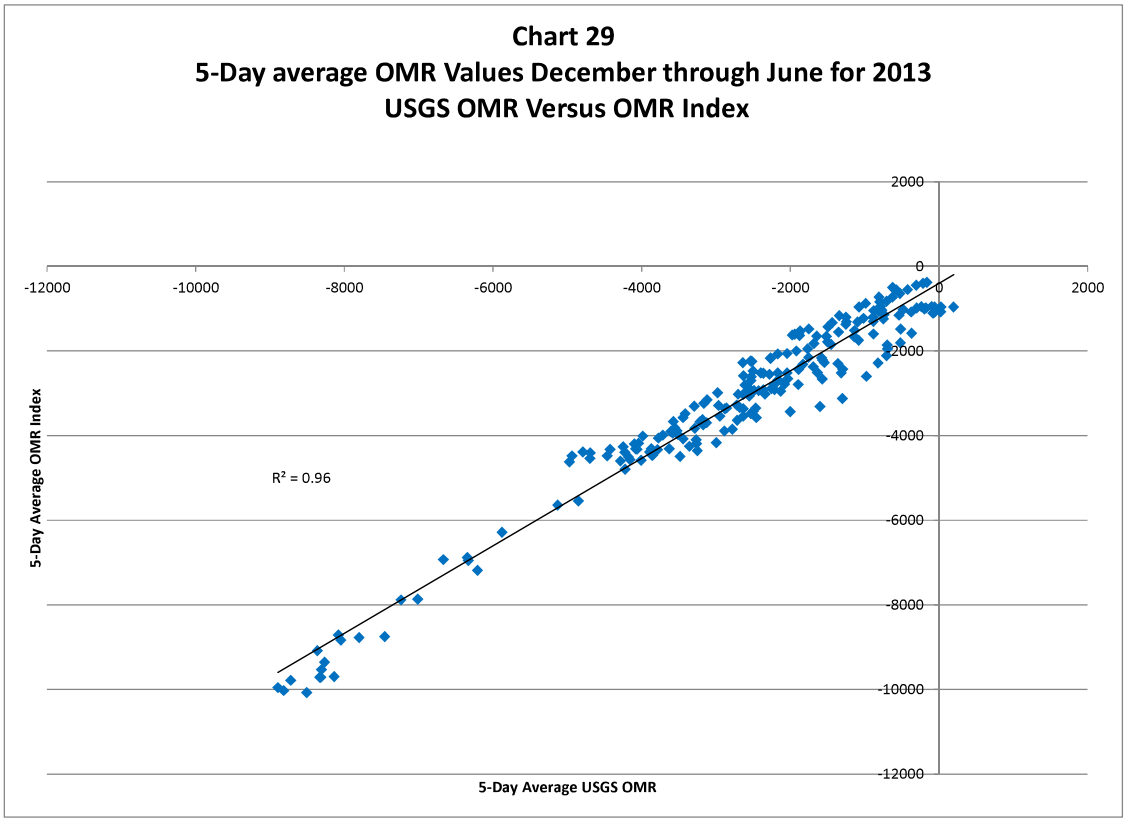
Chart 29
5-Day average OMR Values December through June for 2013
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
R² = 0.96
5-Day Average OMR Index
5-Day Average USGS OMR

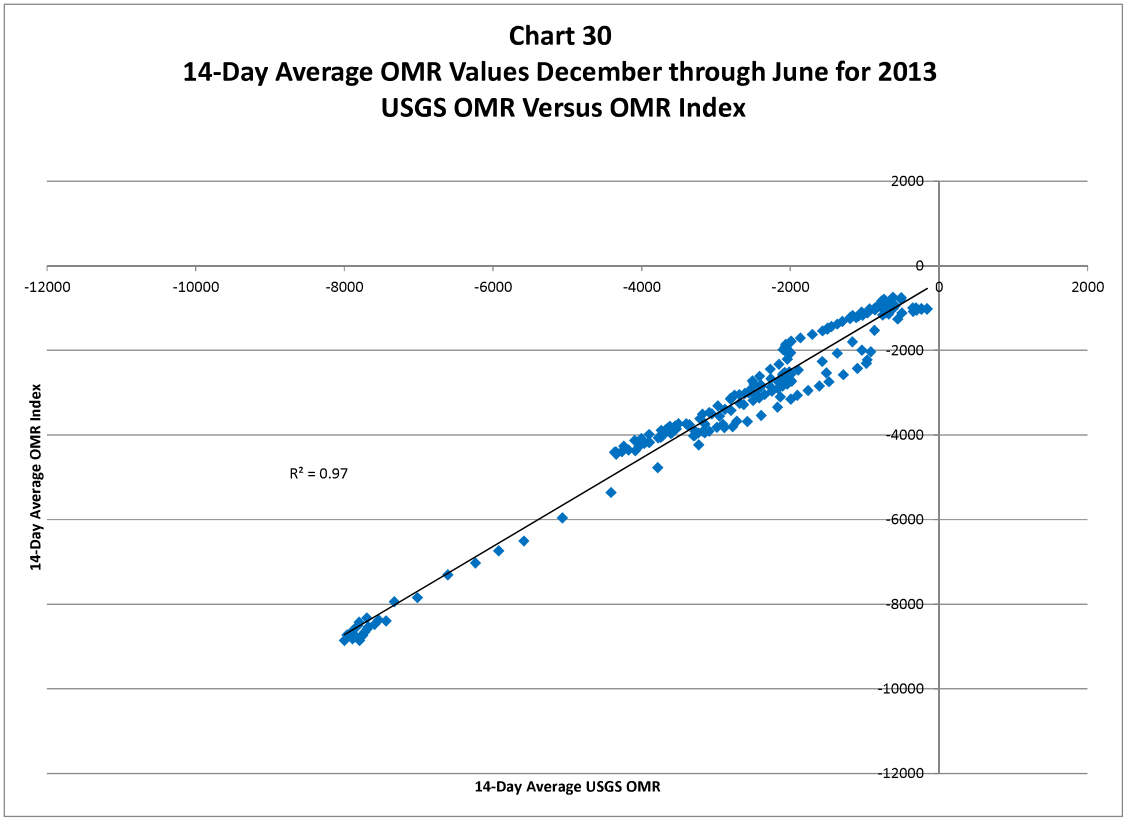
Chart 30
14-Day Average OMR Values December through June for 2013
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
R² = 0.97
14-Day Average OMR Index
14-Day Average USGS OMR

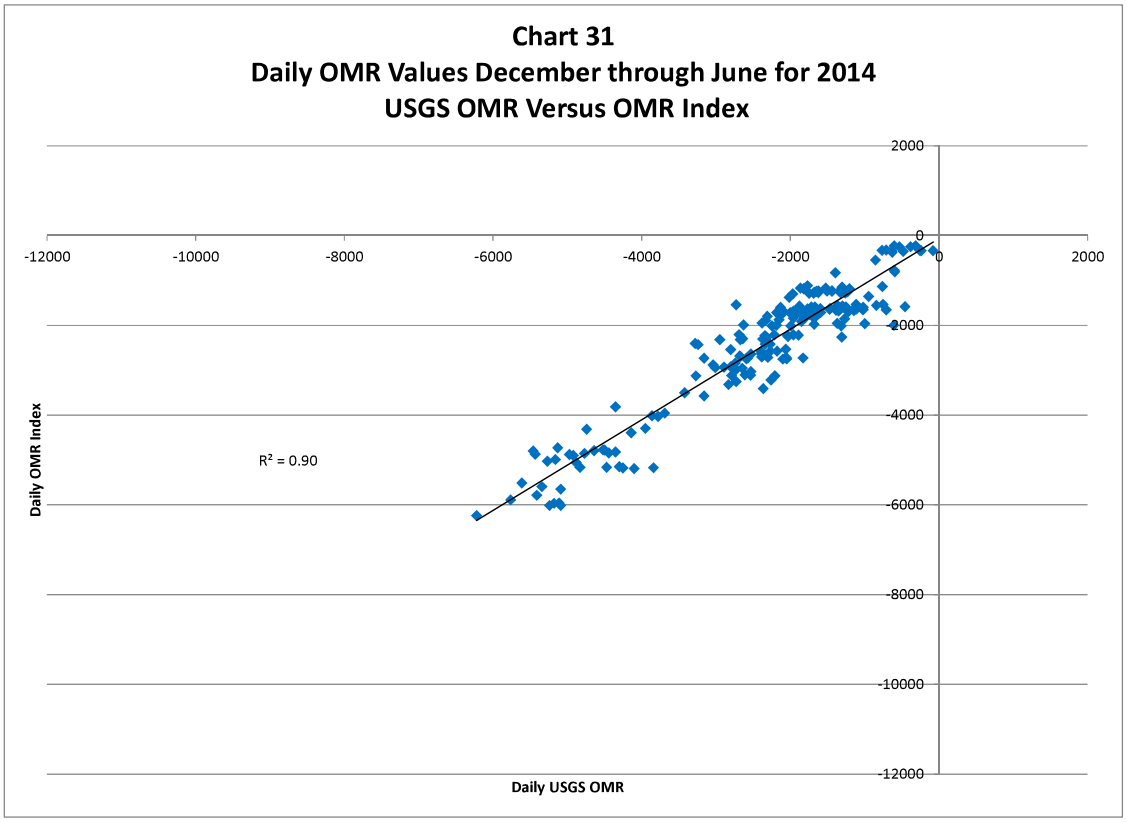
Chart 31
Daily OMR Values December through June for 2014
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
Daily OMR Index
Daily USGS OMR
R² = 0.90

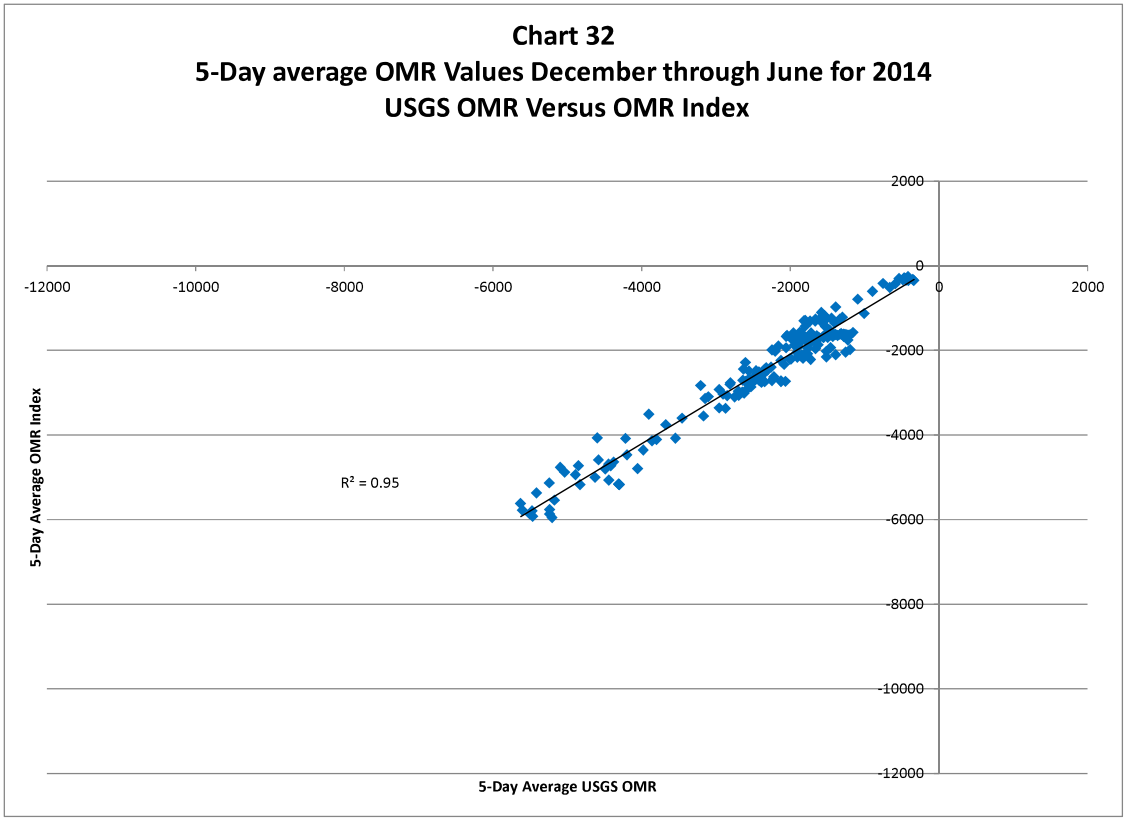
Chart 32
5-Day average OMR Values December through June for 2014
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
5-Day Average OMR Index
5-Day Average USGS OMR
R² = 0.95

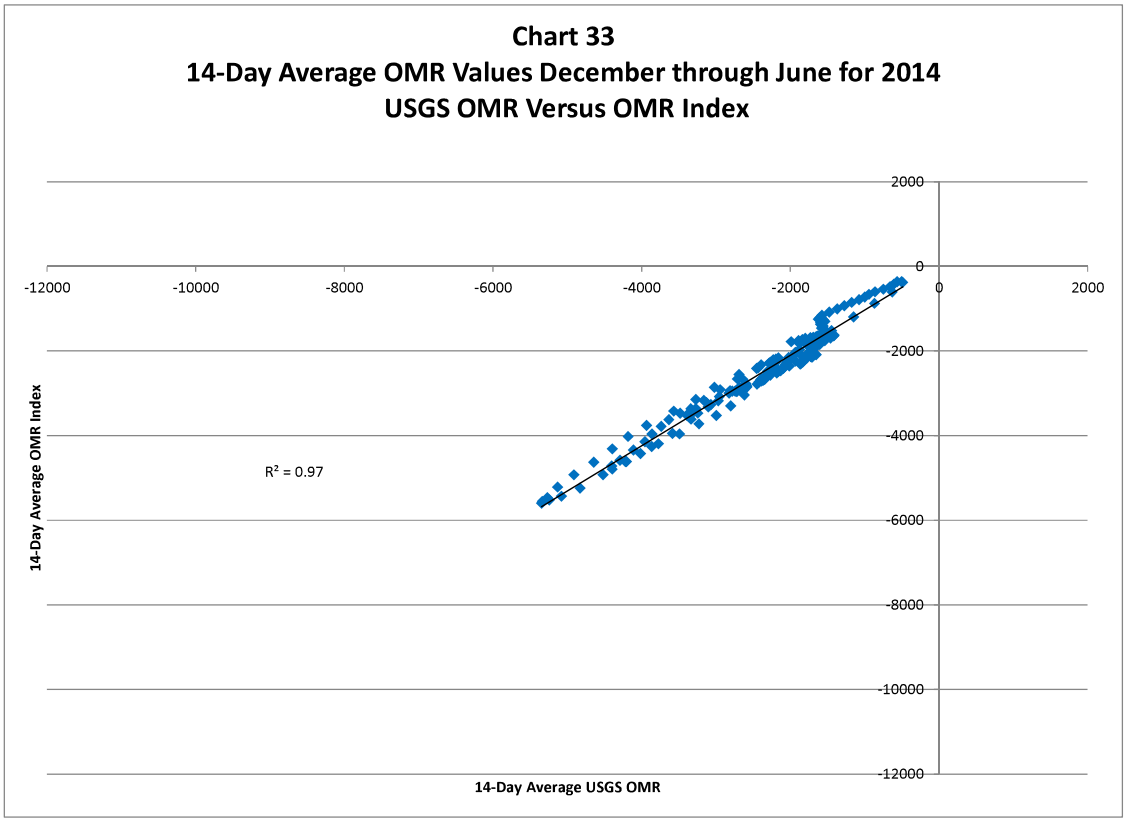
Chart 33
14-Day Average OMR Values December through June for 2014
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
14-Day Average OMR Index
R² = 0.97
14-Day Average USGS OMR

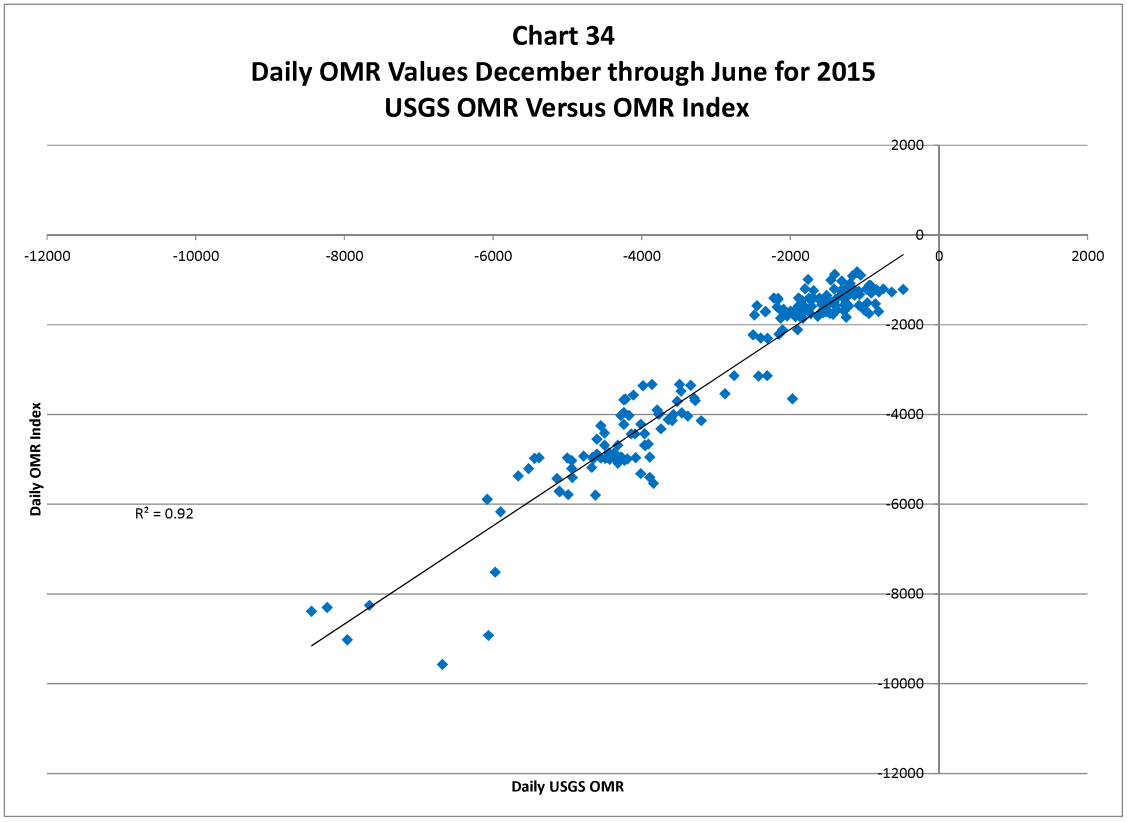
Chart 34
Daily OMR Values December through June for 2015
USGS OMR Versus OMR Index
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
Daily OMR Index
R² = 0.92
Daily USGS OMR

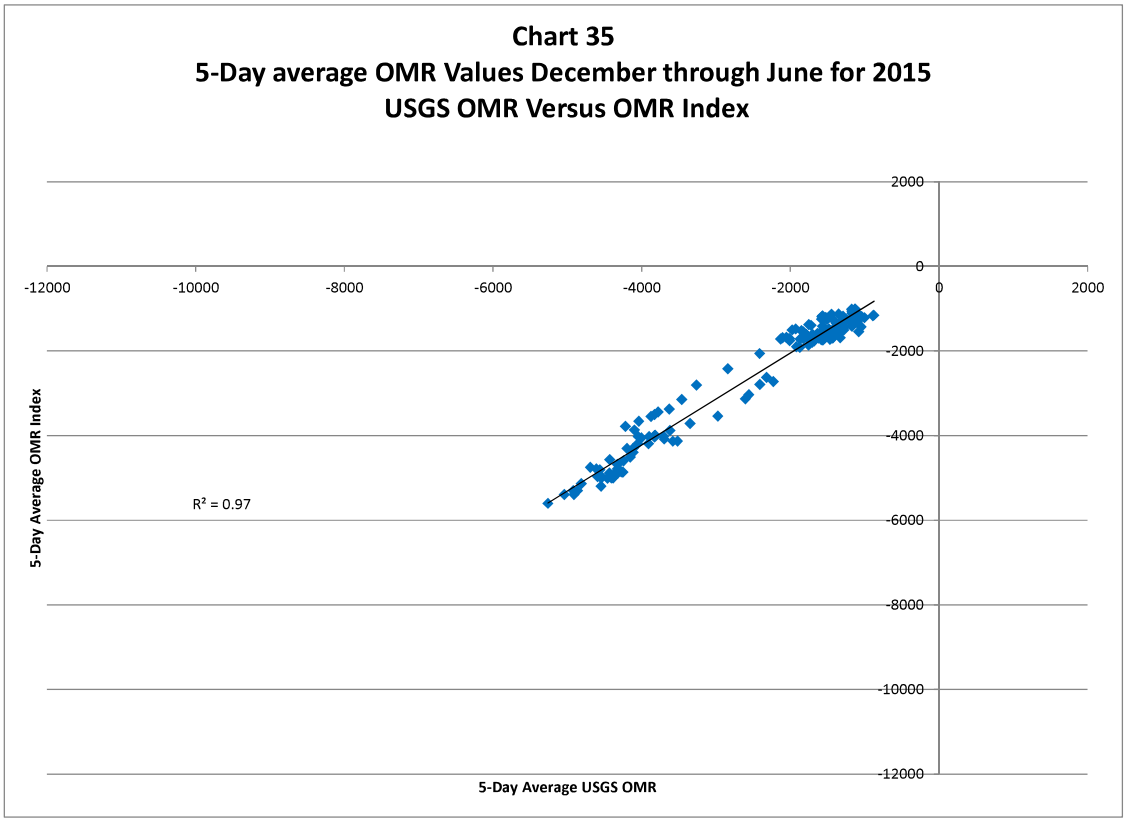
Chart 35
5-Day average OMR Values December through June for 2015
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
5-Day Average OMR Index
R² = 0.97
5-Day Average USGS OMR

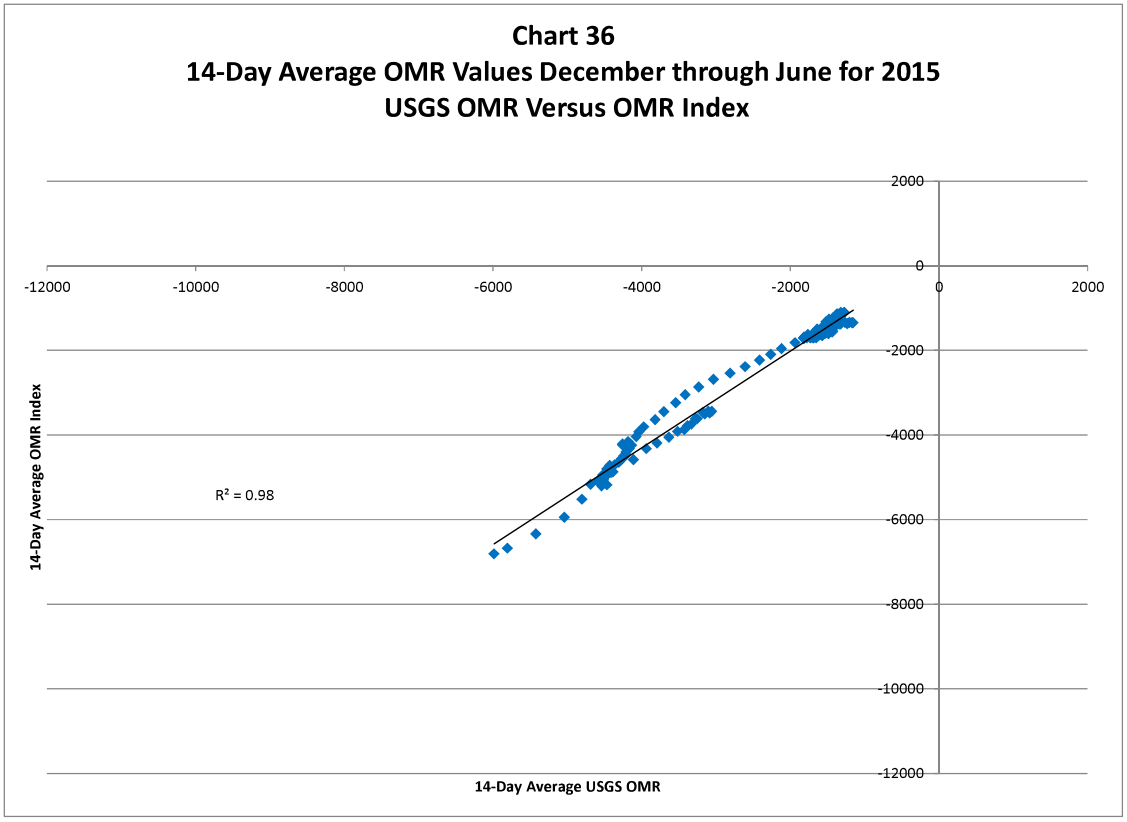
Chart 36
14-Day Average OMR Values December through June for 2015
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
14-Day Average OMR Index
R² = 0.98
14-Day Average USGS OMR

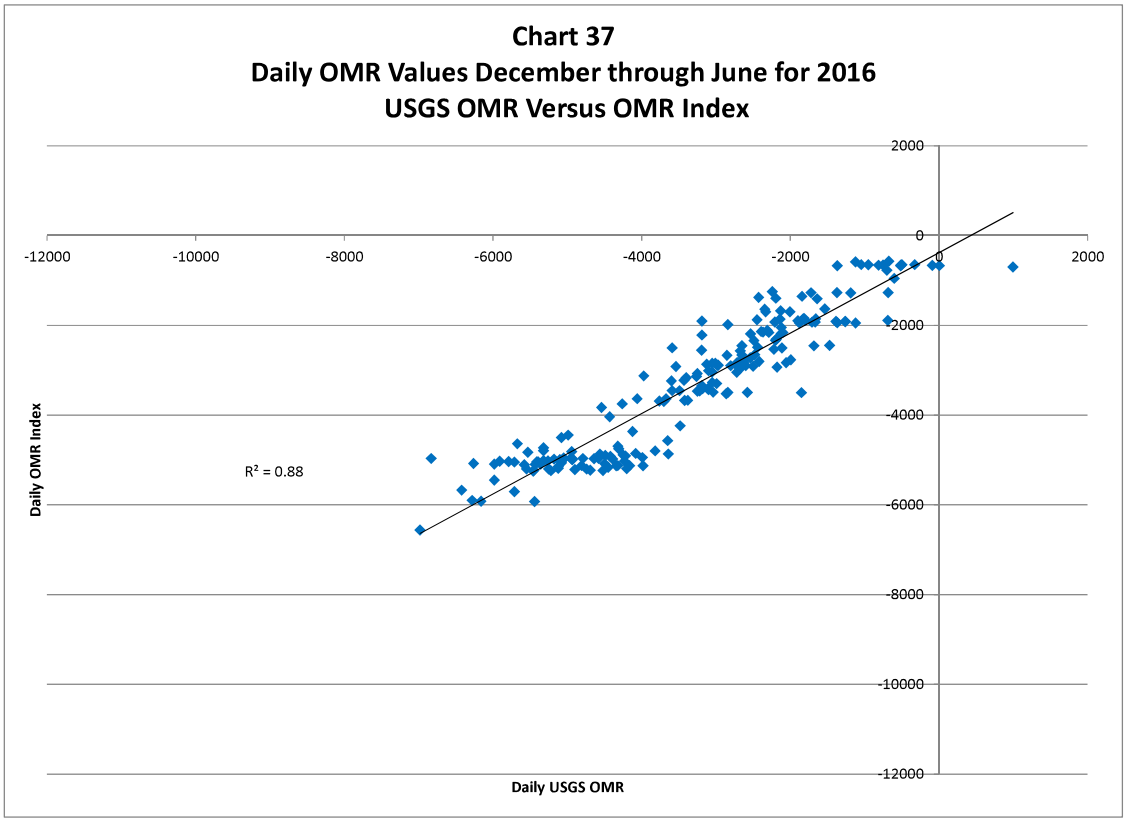
Chart 37
Daily OMR Values December through June for 2016
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
Daily OMR Index
R² = 0.88
Daily USGS OMR

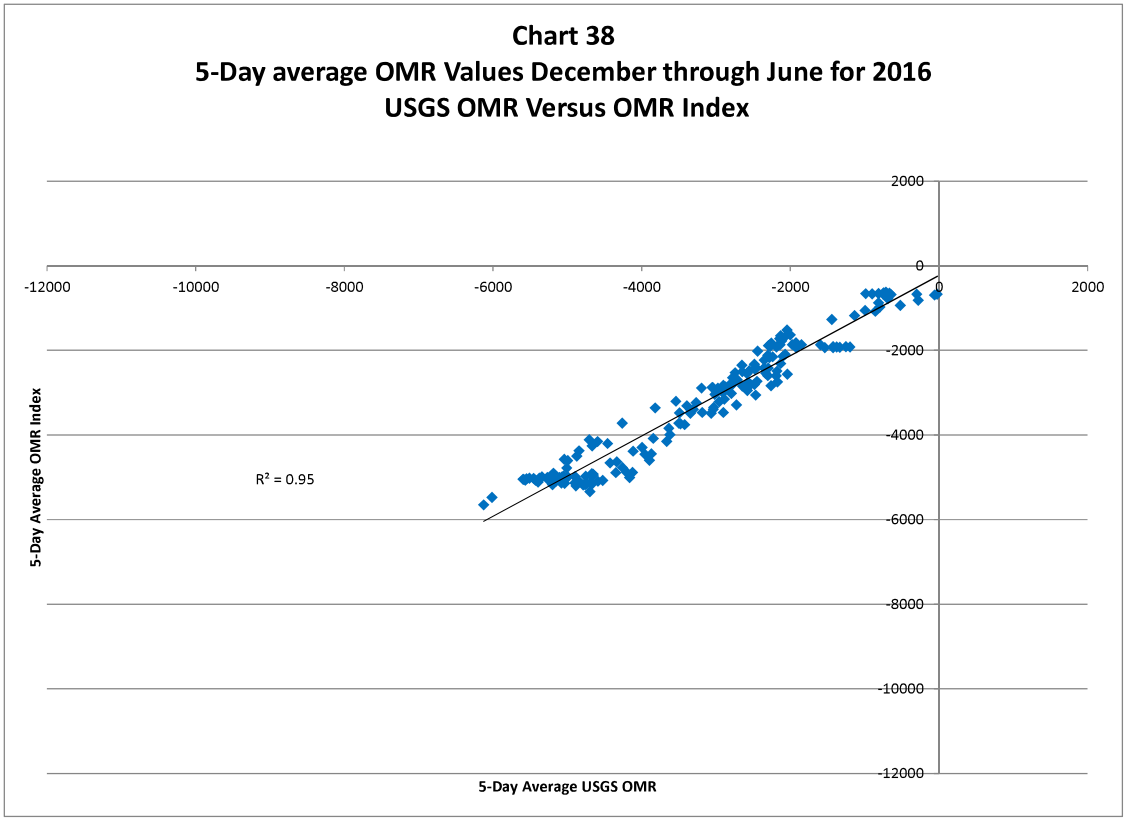
Chart 38
5-Day average OMR Values December through June for 2016
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
5-Day Average OMR Index
R² = 0.95
5-Day Average USGS OMR

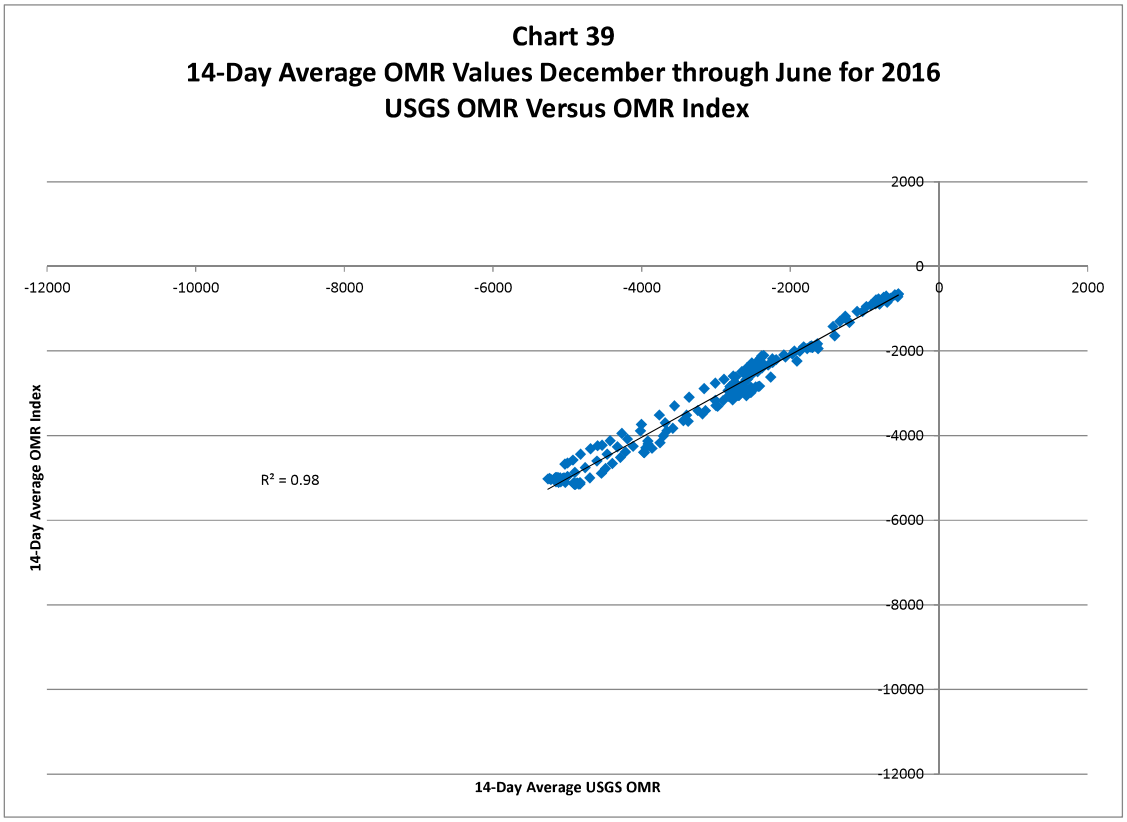
Chart 39
14-Day Average OMR Values December through June for 2016
USGS OMR Versus OMR Index
2000
0
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
-2000
-4000
-6000
-8000
-10000
-12000
14-Day Average OMR Index
R² = 0.98
14-Day Average USGS OMR

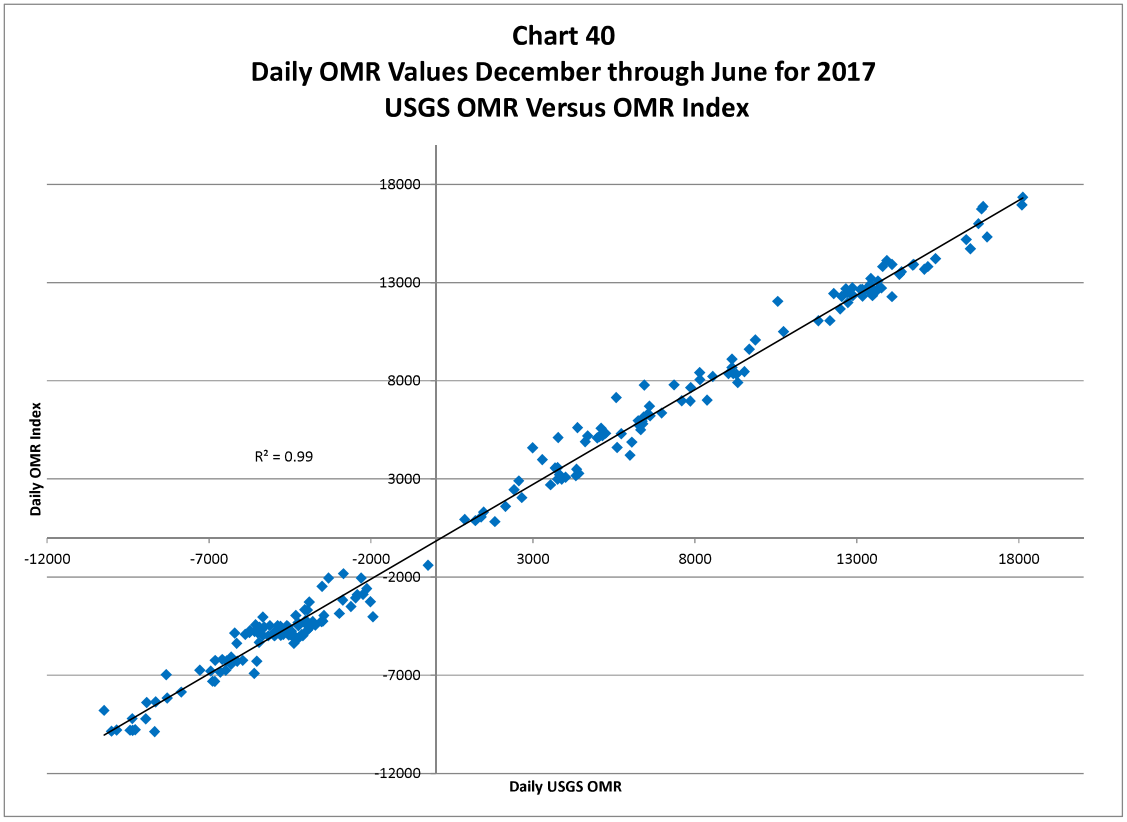
Chart 40
Daily OMR Values December through June for 2017
USGS OMR Versus OMR Index
18000
13000
8000
3000
-2000
-7000
-12000
-12000
-7000
-2000
3000
8000
13000
18000
Daily OMR Index
R² = 0.99
Daily USGS OMR

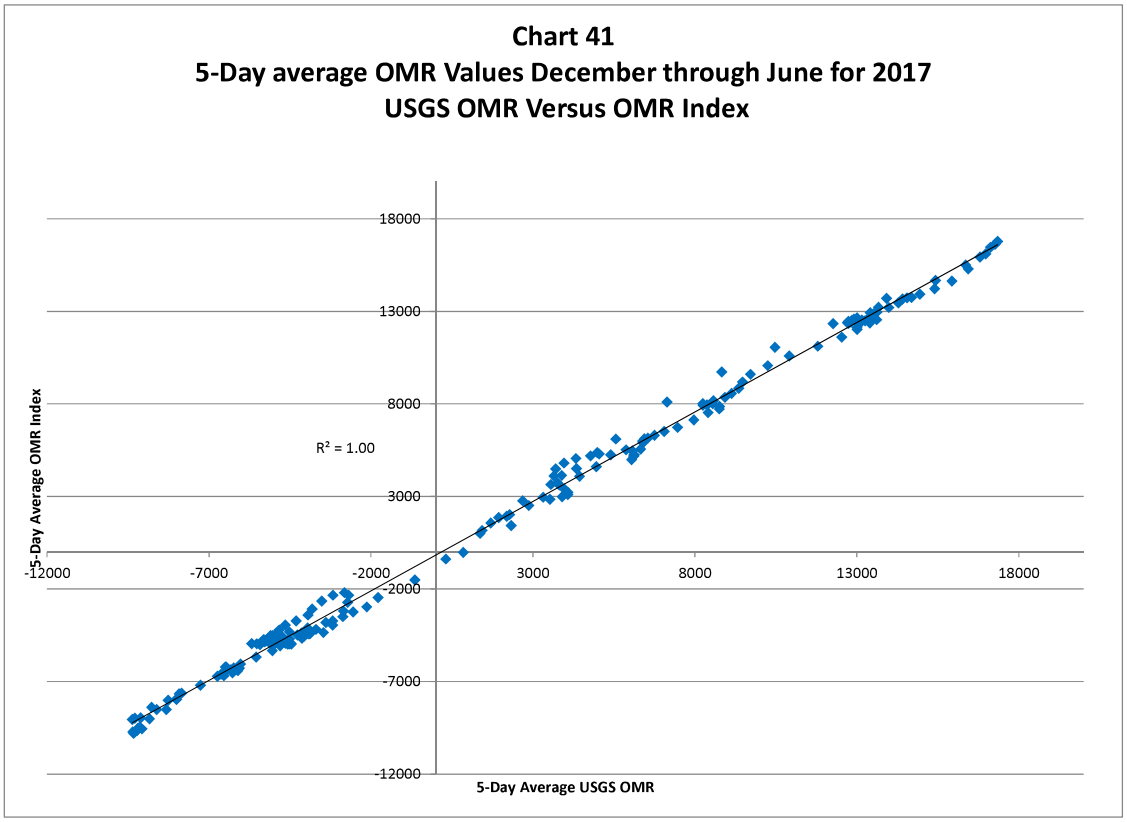
Chart 41
5-Day average OMR Values December through June for 2017
USGS OMR Versus OMR Index
18000
13000
8000
3000
-2000
-7000
-12000
-12000
-7000
-2000
3000
8000
13000
18000
R² = 1.00
-5-Day Average OMR Index
5-Day Average USGS OMR

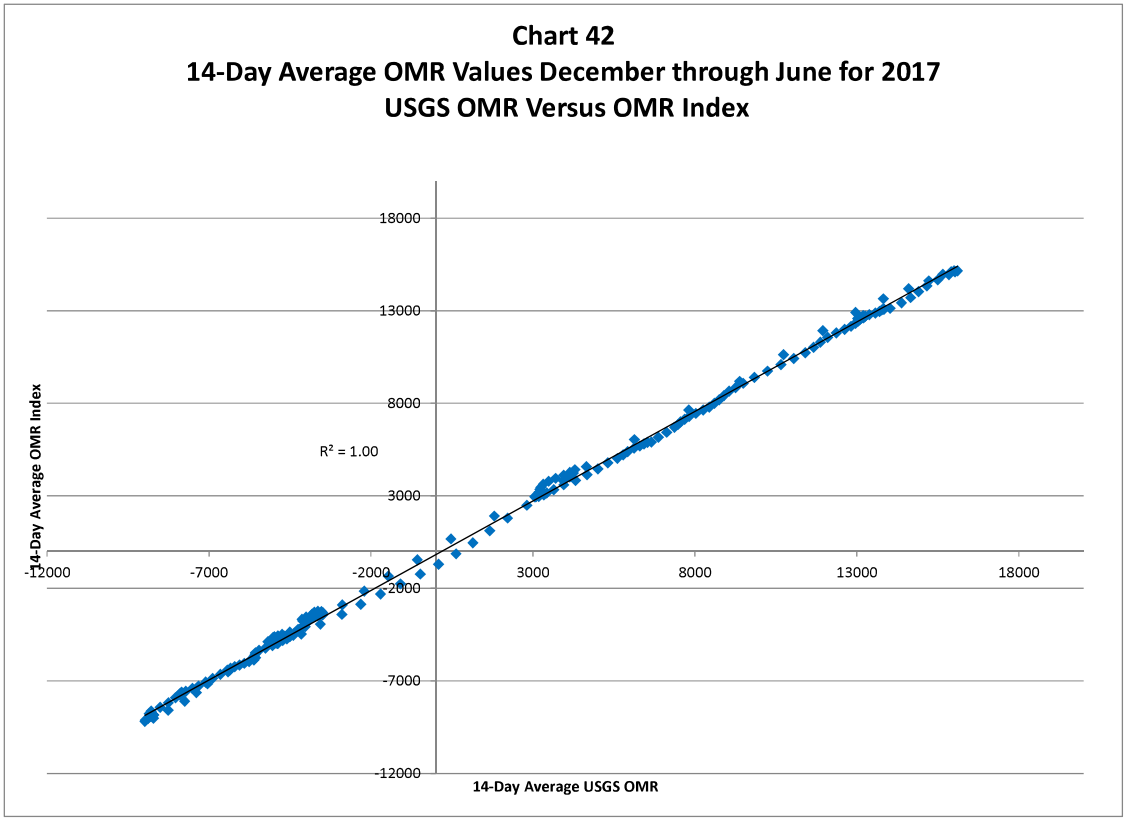
Chart 42
14-Day Average OMR Values December through June for 2017
USGS OMR Versus OMR Index
18000
13000
8000
3000
-2000
-7000
-12000
-12000
-7000
-2000
3000
8000
13000
18000
R² = 1.00
-14-Day Average OMR Index
14-Day Average USGS OMR