

Massachusetts State Treasurer's Office (STO)
Guidelines for Current and Advance Refundings

The STO intends to evaluate refunding opportunities for Massachusetts bonds based on a refunding efficiency approach.¹ In the past, refunding decisions by the STO were based solely on a present value (PV) cashflow savings threshold test. In the future, in addition to PV savings, the STO will also consider in its decision the forfeited option value of the refunded bonds. In case the refunding bonds are also callable, their option value should also be incorporated.

The STO will base its decision on whether the projected PV savings are sufficient in comparison to the net loss of option value. The STO will consider refunding proposals only if the efficiency of the transaction exceeds 85%.

Please screen and analyze refunding opportunities based on the following assumptions:

Calculation of savings

- Determine PV savings by discounting each cashflow using the spot rate derived from the non-call par curve for Commonwealth bonds
- For advance refundings, provide the projected escrow yield

Option valuation

- Use a standard lognormal interest rate model (like Black-Karasinski or Black-Derman Toy)
- Assume 15% short-term volatility and 0% mean reversion factor
- In case of advance refunding, provide the estimated value of the advance refunding option (incremental to the value of the call/current refunding option). If the value of the advance refunding option is ignored, please disclose this fact.
- If the proposal calls for callable refunding bonds, include the option value of the refunding bonds
- Incorporate projected future transaction costs in the calculation of option value(s)

Presentation

- Please use the spreadsheet being sent along with these guidelines as a template for presenting results of the refunding analysis back to the STO

¹ "Refunding efficiency: a generalized approach", Andrew J. Kalotay, Deane Yang, and Frank J. Fabozzi, *Applied Financial Economics Letters*, Vol. 3, Issue 3, May 2007, pages 141-146.

ANDREW KALOTAY

ASSOCIATES, INC.

Interest Rate Volatility Input for Refunding Analysis

April 23, 2013

Issuers of municipal bonds have traditionally used rules of thumb based on present value savings in order to make decisions on when to refund. For example, many will act when a threshold of 3% savings is reached. This is in marked contrast to the corporate and agency world, where issuers usually ensure that they capture a high percentage of the option value being given up. The ratio of savings to forfeited option value is referred to as refunding efficiency.¹

The State Treasurer's Office of the Commonwealth of Massachusetts wants to bring more rigorous analysis to bear on its refunding decisions, and has decided to use refunding efficiency rather than present value savings targets. In order to calculate the option value that is part of the efficiency calculation, it is necessary to specify an appropriate interest rate volatility.² The STO, in consultation with its advisors, Andrew Kalotay Associates, currently recommends 15%.

Most sophisticated issuers in the taxable market use security-specific volatilities derived from the swaption volatility matrix according to the bond's maturity and remaining time to call. In the municipal market, where information is imperfect, we recommend a simpler approach.

A single volatility has the advantage of allowing the STO to view all submitted refunding proposals on an apples-to-apples basis. If each proposing bank was allowed to specify its own volatility, this would not be possible.

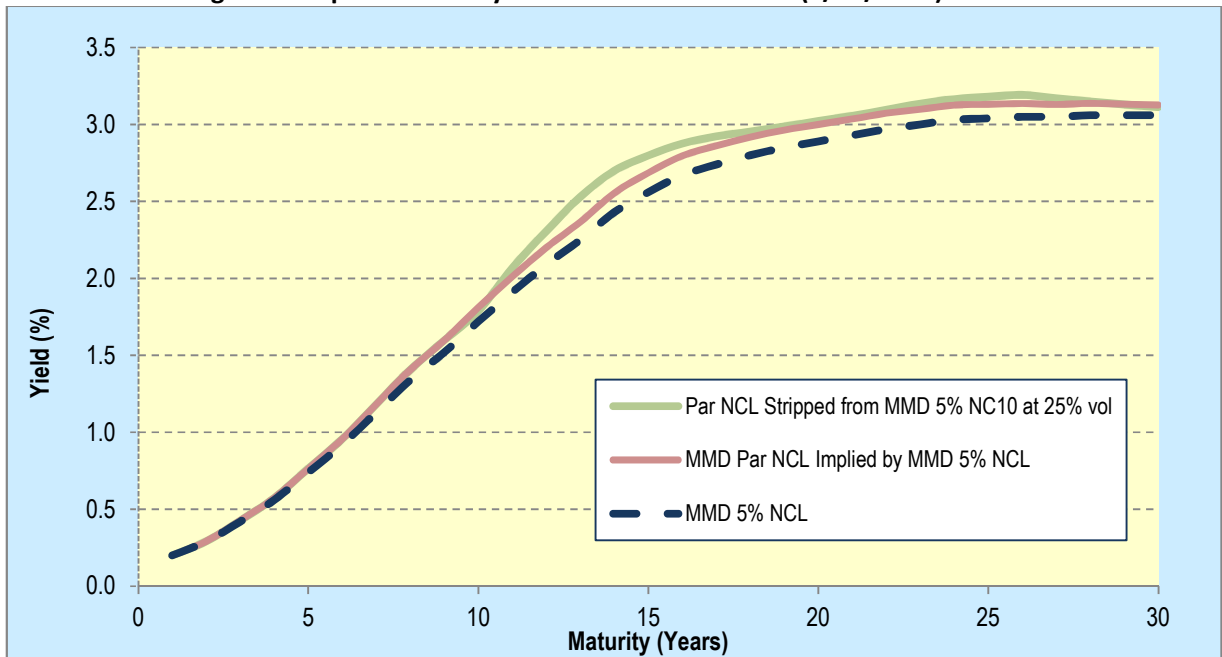
A question that may arise is whether the recommended volatility of 15% is too low or too high. Option value, which increases with volatility, forms the denominator in the refunding efficiency ratio. Thus, too high a volatility understates the efficiency, which in turn triggers fewer refundings. Conversely, too low a volatility overstates the efficiency, which results in refunding too early.

A good starting point is to estimate the implied volatility of new callable issues. Unfortunately, in the municipal market the information available for this purpose is limited. In this vacuum, the MMD yield curves are relied on as a consensus benchmark.

¹ As discussed in the guidelines provided by the STO.

² This refers to the volatility of the short-term rate that would be an input, with zero mean reversion, into a Black-Karasinski or a Black-Derman-Toy interest rate process. The implied volatilities of longer rates would be lower than that of the of the short-term rate.

Figure 1: Implied Volatility in MMD 5% NC10 Curve (4/19/2013)



MMD provides both a 5% callable (NC10) curve and a 5% optionless curve. We estimated the interest rate volatility implied by the relationship between these two curves. The results are shown on the Figure 1 above. It turns out that a volatility of 25% comes close to explaining the difference between MMD’s 5% callable and optionless curves.

We then applied a couple of sanity checks. In general, the better the credit, the more the market charges (in terms of implied volatility) for embedded call options. For example, the GSE’s are charged a high percentage of swaption volatility levels for their callable issues. At the other extreme, the implied volatility of high yield callable bonds is negligible because investors are not averse to receiving their principal back early, in light of the credit risk.

For reference, Table 1 below indicates that the volatility for swaptions, exercisable 10 years from now, ranges from 23.0% to 26.7% — an upper bound, but obviously too high for municipalities.

Table 1: Volatilities of At-The-Money Swaptions Exercisable in 10 Years (4/22/13)

Underlying Swap Term (yrs)	11	12	15	20	25	30
Volatility (%)	26.7	26.4	25.2	24.6	23.4	23.0

Source: Bloomberg

The second sanity check is to determine the implied coupon premium for par callable bonds relative to par non-callable bonds. Using 30NC10 as a reference point, our discussion with muni professionals suggests that most consider a 20-30 basis point

coupon premium to be reasonable. Table 2 below shows that a volatility of 15% applied to the Massachusetts par NCL curve in the Refunding Example provided by the STO would result in a par callable coupon premium (relative to par NCL) of about 25 basis points.

Table 2: Is a Volatility of 15% Reasonable?

Interest Rate Volatility (%)	30NC10 Par Coupon Premium Over Par 30NCL (bps)
8	9
15 (Recommended by STO)	25
25 (Implied MMD volatility)	47

In conclusion, under current market conditions, using a single volatility of 15% is not unreasonable. The STO may revise this number if there is a sustained and significant change in the interest rate environment.



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Illustrative Refunding Analysis According to Massachusetts State Treasury Guidelines

Prepared on behalf of:



April 19, 2013

Market Inputs

- ✓ New issue scale (YTC or YTM) for the Commonwealth of Massachusetts

Show coupon by maturity; indicate call provision

E.g. 5% for all maturities, NC-10 at par

- ✓ Treasury, SLGS, or Agency rates used in advance refundings

Throughout this document:

- ✓ indicates mandatory inclusion with refunding proposals

Convert Market Scale Into Format for Standard Bond Analytics*

Use 15% interest rate volatility to calculate:

- ✓ Optionless (non-call life) par yield curve
- ✓ Spot (pure discount) rates

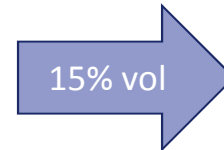
Note: Mass. may change vol. specification from time to time, depending on market conditions

**Such as would be used on the Bloomberg OAS1 page, for example*

Scale Conversion Example

Commonwealth of Massachusetts
General Obligation Bonds
Indicative Interest Rates as of April 2, 2013

		Premium Coupons 10 year par call			
	MMD	Maturity	Coupon	Spread to MMD	Yield
1	0.20%	2014	5.000%	0.00	0.20%
2	0.31%	2015	5.000%	3.00	0.34%
3	0.47%	2016	5.000%	6.00	0.53%
9	1.71%	2	5.000%	22.00	1.93%
10	1.89%	3	5.000%	23.00	2.12%
11	2.02%	4	5.000%	25.00	2.27%
14	2.39%	7	5.000%	25.00	2.64%
15	2.48%	8	5.000%	25.00	2.73%
16	2.54%	9	5.000%	25.00	2.79%
28	3.07%	21	5.000%		3.07%
29	3.08%	22	5.000%		3.08%
30	3.09%	23	5.000%	22.00	3.31%



iteRate - 1.0

Maturity (yrs)	Par NCL Rate	YTC	YTM
1.00	0.200	0.200	0.200
2.00	0.344	0.340	0.340
3.00	0.541	0.530	0.530
9.00	2.016	1.930	1.930
10.00	2.213	2.120	2.120
11.00	2.540	2.270	2.464
30.00	3.696	3.310	4.162

Conversion methodology described in:

What Makes the Muni Yield Curve Rise?

Journal of Fixed Income (Winter 2009)

Treasury, SLGS, or Agency NCL Rates

Time	Rate
0.083	0.090%
0.25	0.093%
0.5	0.094%
1	0.165%
2	0.237%
3	0.342%
5	0.751%
7	1.223%
10	1.836%
20	2.779%
30	3.075%

Provide at least up to the longest relevant call date

Transaction Costs

- ✓ Current underwriting fee
 - Affects savings in the contemplated transaction
- ✓ Schedule of fees by maturity
 - Needed to capture costs in future refundings
 - Reduces option value

Underwriting Fees Example

AccruedAndFeeSource	NewIssue
Fee	0.5%
PVDate	4/2/2013

Current fee reduces savings
(*Show for each bond*)

Applicable to future refunding opportunities; reduces option value of refunding candidate and of callable replacement bond

Underwriting	
Maturity	Fees
1	0.1%
1.5	0.15%
2	0.2%
3	0.25%
4	0.3%
5	0.35%
7	0.4%
10	0.45%
15	0.5%
20	0.55%
30	0.6%

Analytical Results

Outstanding bond

- ✓ PV of cash flows (to nominal maturity)
- ✓ Option value (call, advance refunding, total)

Replacement bond

- ✓ PV of cash flows (to nominal maturity)
- ✓ Option value (if relevant)

Refunding Efficiency

Use Generalized Refunding Efficiency Formula

$$Efficiency_{generalized} = \frac{PV \text{ Savings}}{Loss \text{ of Option Value}}$$

Present only those candidates with efficiency of at least 50%

Refunding Efficiency: A Generalized Approach

Applied Financial Economic Letters, 2007

Efficiency when the refunding bond is also callable

Refunding Candidate

MUNICIPAL BOND DESCRIPTION		Page 1/ 4	
MASSACHUSETTS ST		CUSIP:57582PFQ(8)	
CONS LN-SER C		BBGID:BBG0010WDGM2	
TICKER: MAS	CPN: 5 $\frac{1}{4}$	MATURITY: 8/01/2025 DATED: 8/16/2007 STATE:MA	
9) TDH MSRB Trades		24K	
SECURITY INFORMATION		TRADING INFORMATION	
ISSUE TYPE	GENERAL OBLIGATION LTD	1ST SETTLE DATE	8/16/2007
MATURITY TYPE	1) CALL	NEXT SETTLEMENT DATE	4/15/2013
COUPON TYPE	FIXED	INTEREST ACCRUAL DATE	8/16/2007
PRICE/YIELD @ ISSUE	106.709/ 4.410	1ST COUPON DATE	2/01/2008
COUPON FREQ.	SEMI-ANNUAL	NEXT PAR CALL	8/01/2017 @ 100
TAX PROVISION	FED & ST TAX-EXEMPT	WEEK OF SALE	8/06/2007
FORM	BOOK-ENTRY	FORMAL AWARD	8/08/2007 13:00
		FIRST TRADE	8/08/2007 14:00

Refunding Efficiency Example



Advance Refunding Calculator

206.20121217

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AccruedAndFeeSource	NewIssue
Fee	0.5%
PVDate	4/2/2013

Price		122.70
Coupon	5.000%	5.000%

Refunded		Call	
Dated	8/16/2007	Volatility	15%
Maturity	8/1/2025	Type	American
Coupon	5.25%	Delay	0
_Daycount	30/360	Date	8/1/2017
_Frequency	SemiAnnual	CallPrice	100
_Method	Muni	_FirstPar	
_Issue		_Freq	SemiAnnual
_First		_LastPar	
_Last			
_Face	61,000,000.00		
_ExDays			
_PayDay			
_Redemption			

Refunding		Call	
Dated	4/2/2013	Volatility	15%
Maturity	8/1/2025	Type	American
Coupon	5.000%	Delay	0
_Daycount	30/360	Date	8/1/2023
_Frequency	SemiAnnual	CallPrice	100
_Method	Muni	_FirstPar	
_Issue		_Freq	Annual
_First		_LastPar	
_Last			
_Face	60,279,359.65		
_ExDays			
_PayDay			
_Redemption			

Report	
PVDate	4/2/2013
Savings	3,103,470.56
OptionLoss	4,574,884.04
Efficiency	67.84%
OldPV	77,522,795.71
NewPV	74,419,325.15
OldCall	4,953,469.30
OldAdvRef	34,884.98
OldOption	4,988,354.28
NewOption	413,470.24

Cash Flow Savings Example

Date	Refunded				Refunding			Net Savings			
	Interest	Principal	PV	Spot	Discount	Interest	Principal	PV	CashFlow	PV	
4/2/2013								0	0	0	0
8/1/2013	1,601,250	0	1,600,192	0.200%	0.99934	996,281	0	995,623	604,969	604,570	
2/1/2014	1,601,250	0	1,598,594	0.200%	0.99834	1,506,984	0	1,504,484	94,266	94,110	
8/1/2014	1,601,250	0	1,595,954	0.249%	0.99669	1,506,984	0	1,502,000	94,266	93,954	
2/1/2015	1,601,250	0	1,591,879	0.321%	0.99415	1,506,984	0	1,498,165	94,266	93,714	
8/1/2015	1,601,250	0	1,586,007	0.411%	0.99048	1,506,984	0	1,492,638	94,266	93,369	
2/1/2016	1,601,250	0	1,578,341	0.510%	0.98569	1,506,984	0	1,485,423	94,266	92,917	
8/1/2016	1,601,250	0	1,569,566	0.601%	0.98021	1,506,984	0	1,477,165	94,266	92,401	
2/1/2017	1,601,250	0	1,559,848	0.685%	0.97414	1,506,984	0	1,468,019	94,266	91,829	
8/1/2017	1,601,250	0	1,546,335	0.807%	0.96570	1,506,984	0	1,455,302	94,266	91,033	
2/1/2018	1,601,250	0	1,529,762	0.948%	0.95535	1,506,984	0	1,439,704	94,266	90,057	
8/1/2021	1,601,250	0	1,366,257	1.914%	0.85324	1,506,984	0	1,285,825	94,266	80,432	
2/1/2022	1,601,250	0	1,337,787	2.046%	0.83546	1,506,984	0	1,259,031	94,266	78,756	
8/1/2022	1,601,250	0	1,310,079	2.163%	0.81816	1,506,984	0	1,232,954	94,266	77,125	
2/1/2023	1,601,250	0	1,282,327	2.272%	0.80083	1,506,984	0	1,206,836	94,266	75,491	
8/1/2023	1,601,250	0	1,246,999	2.435%	0.77877	1,506,984	0	1,173,588	94,266	73,411	
2/1/2024	1,601,250	0	1,207,062	2.626%	0.75383	1,506,984	0	1,136,002	94,266	71,060	
8/1/2024	1,601,250	0	1,170,043	2.788%	0.73071	1,506,984	0	1,101,162	94,266	68,881	
2/1/2025	1,601,250	0	1,134,082	2.937%	0.70825	1,506,984	0	1,067,319	94,266	66,764	
8/1/2025	1,601,250	61,000,000	42,977,153	3.074%	0.68652	1,506,984	60,279,360	42,417,702	814,906	559,451	

Spot rates derived from input scale

Note That ...

- At a 15% interest rate volatility, the implied 30-year NCL rate is 3.696% (Scale Conversion Example)
- The spot rate for discounting a 2/1/2025 cash flow is 3.074% (Cash Flow Savings Example)
- According to the Refunding Efficiency Example,
 - PV savings=\$3.103MM
 - Option value of the outstanding 5.25% bonds=\$4.988MM,
(\$4.953MM call, \$0.035MM advance refunding)
 - Option value of the refunding bond=\$0.413MM
 - Net loss of option value=\$4.575MM
 - Refunding efficiency=67.85%

Comments on Analytics

- Results calculated using Kalotay's iteRate™ and Advance Refunding Calculator™
 - However, proposals may utilize any suitable software
- Discounting and call option valuation should follow standard 'textbook' methodology
 - See "Valuation of Municipal Bonds with Embedded Options"
Handbook of Municipal Securities, 2008, ed. F. Fabozzi
- Value of the advance refunding option was calculated using Kalotay's proprietary algorithm
 - Reasonable alternatives are acceptable
 - See "The Timing of Advance Refunding of Tax-Exempt Municipal Bonds" – Kalotay and May
Municipal Finance Journal (Fall 1998)

Contact Information

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The Commonwealth of Massachusetts
 General Obligation Bonds
 Refunding Analysis

Rates as of [add date]
 Delivery Date 5/1/2013
 Costs of Issuance \$5.00
 Bonds Ranked by: Refunding efficiency, high to low

Refunding Efficiency
 Volatility Assumption 15%
 Interest Rate Model Black-Karasinski

Existing Bond											New Bond				Negative Arbitrage		
CUSIP	Series	Coupon	Maturity	Par	Call Date	Call Price	Yrs. to Call	Yrs. to Maturity	Call to Maturity Spread	Coupon	Current Market Yield	Price	Maturity	Escrow Yield	\$ Negative Arb	% of Par	
1	57582N7G4	Consolidated Loan of 2006, Series D	5.000%	8/1/2019	15,990,000	8/1/2016	100.00	3.25	6.25	3.00	2.000%	1.260%		0.400%	(474,362)	-2.97%	
2	57582N7H2	Consolidated Loan of 2006, Series D	4.250%	8/1/2020	6,620,000	8/1/2016	100.00	3.25	7.26	4.00	2.000%	1.520%		0.400%	(251,252)	-3.80%	
3	57582N7K5	Consolidated Loan of 2006, Series D	4.300%	8/1/2021	2,910,000	8/1/2016	100.00	3.25	8.26	5.00	2.000%	1.760%		0.400%	(133,648)	-4.59%	
4	57582PFH8	Consolidated Loan of 2007, Series C	5.000%	8/1/2019	31,000,000	8/1/2017	100.00	4.25	6.25	2.00	2.000%	1.260%		0.620%	(903,571)	-2.91%	
5	57582PKK1	Consolidated Loan of 2007, Series C	5.250%	8/1/2021	34,000,000	8/1/2017	100.00	4.25	8.26	4.00	2.000%	1.760%		0.620%	(1,754,794)	-5.16%	
6	57582PFM7	Consolidated Loan of 2007, Series C	5.250%	8/1/2022	53,000,000	8/1/2017	100.00	4.25	9.26	5.00	2.000%	1.960%		0.620%	(3,200,822)	-6.04%	
7	57582PFJ4	Consolidated Loan of 2007, Series C	5.000%	8/1/2020	32,000,000	8/1/2017	100.00	4.25	7.26	3.00	2.000%	1.520%		0.620%	(1,303,942)	-4.07%	
8	57582PFN5	Consolidated Loan of 2007, Series C	5.250%	8/1/2023	58,000,000	8/1/2017	100.00	4.25	10.26	6.00	2.250%	2.150%		0.620%	(3,982,602)	-6.87%	

Escrow Efficiency	PV Savings		Break-Even Analysis		Option Value (% old par)			Refunding Efficiency	Cumulative Results		
	\$ Savings	% of Par	Break-Even Rate Increase to Eliminate Savings	PV01	Old Bond	New Bond	Net Loss		Refunded Par	\$ Savings	% of Par
70.2%	1,117,273	6.99%	0.25%					99%	15,990,000	1,117,273	6.99%
60.0%	376,211	5.68%	0.26%					98%	22,610,000	1,493,484	6.61%
57.7%	182,515	6.27%	0.24%					97%	25,520,000	1,675,999	6.57%
54.3%	1,074,062	3.46%	0.22%					96%	56,520,000	2,750,061	4.87%
56.5%	2,275,123	6.69%						95%	90,520,000	5,025,184	5.55%
56.1%	4,086,293	7.71%						94%	143,520,000	9,111,477	6.35%
54.4%	1,554,512	4.86%						93%	175,520,000	10,665,989	6.08%
55.0%	4,861,211	8.38%						92%	233,520,000	15,527,200	6.65%

The Commonwealth of Massachusetts
General Obligation Bonds
Refunding Analysis

Mass. G.O. Scale for Refunding Bonds

Maturity	Rate
1	0.00%
2	0.00%
3	0.00%
4	0.00%
5	0.00%
6	0.00%
7	0.00%
8	0.00%
9	0.00%
10	0.00%
11	0.00%
12	0.00%
13	0.00%
14	0.00%
15	0.00%
16	0.00%
17	0.00%
18	0.00%
19	0.00%
20	0.00%
21	0.00%
22	0.00%
23	0.00%
24	0.00%
25	0.00%
26	0.00%
27	0.00%
28	0.00%
29	0.00%
30	0.00%

Mass. G.O. Spot Rate Curve

Maturity	Rate
1	0.00%
2	0.00%
3	0.00%
4	0.00%
5	0.00%
6	0.00%
7	0.00%
8	0.00%
9	0.00%
10	0.00%
11	0.00%
12	0.00%
13	0.00%
14	0.00%
15	0.00%
16	0.00%
17	0.00%
18	0.00%
19	0.00%
20	0.00%
21	0.00%
22	0.00%
23	0.00%
24	0.00%
25	0.00%
26	0.00%
27	0.00%
28	0.00%
29	0.00%
30	0.00%

The Commonwealth of Massachusetts
 General Obligation Bonds
 Refunding Analysis

Summary of Refunding Results	Current Market Rates	Scenario Analysis	
		25 bps Decrease	25 bps Increase
Par Amount Refunded	\$ -	\$ -	\$ -
Refunding Par Amount	\$ -	\$ -	\$ -
Average Life			
Arbitrage Yield			
All-In TIC			
Escrow Yield			
Gross Savings (\$)	\$ 18,000,000	\$ -	\$ -
PV Savings (\$)	\$ -	\$ -	\$ -
PV Savings (%)			
Weighted Average Efficiency	95%	96%	94%
Negative Arbitrage	\$ -	\$ -	\$ -

Principal Amortization (current market rates)	
Maturity	Par
8/1/2013	\$ -
8/1/2014	10,000,000
8/1/2015	12,000,000
8/1/2016	13,000,000
8/1/2017	14,000,000
8/1/2018	15,000,000
8/1/2019	16,000,000
8/1/2020	17,000,000
8/1/2021	18,000,000
8/1/2022	19,000,000
Total	\$ 134,000,000

Annual Budgetary Savings (current market rates)	
Fiscal Year	Gross Savings
2014	\$ -
2015	2,000,000
2016	2,500,000
2017	1,000,000
2018	3,000,000
2019	2,000,000
2020	3,500,000
2021	250,000
2022	1,750,000
2023	2,000,000
Total	\$ 18,000,000