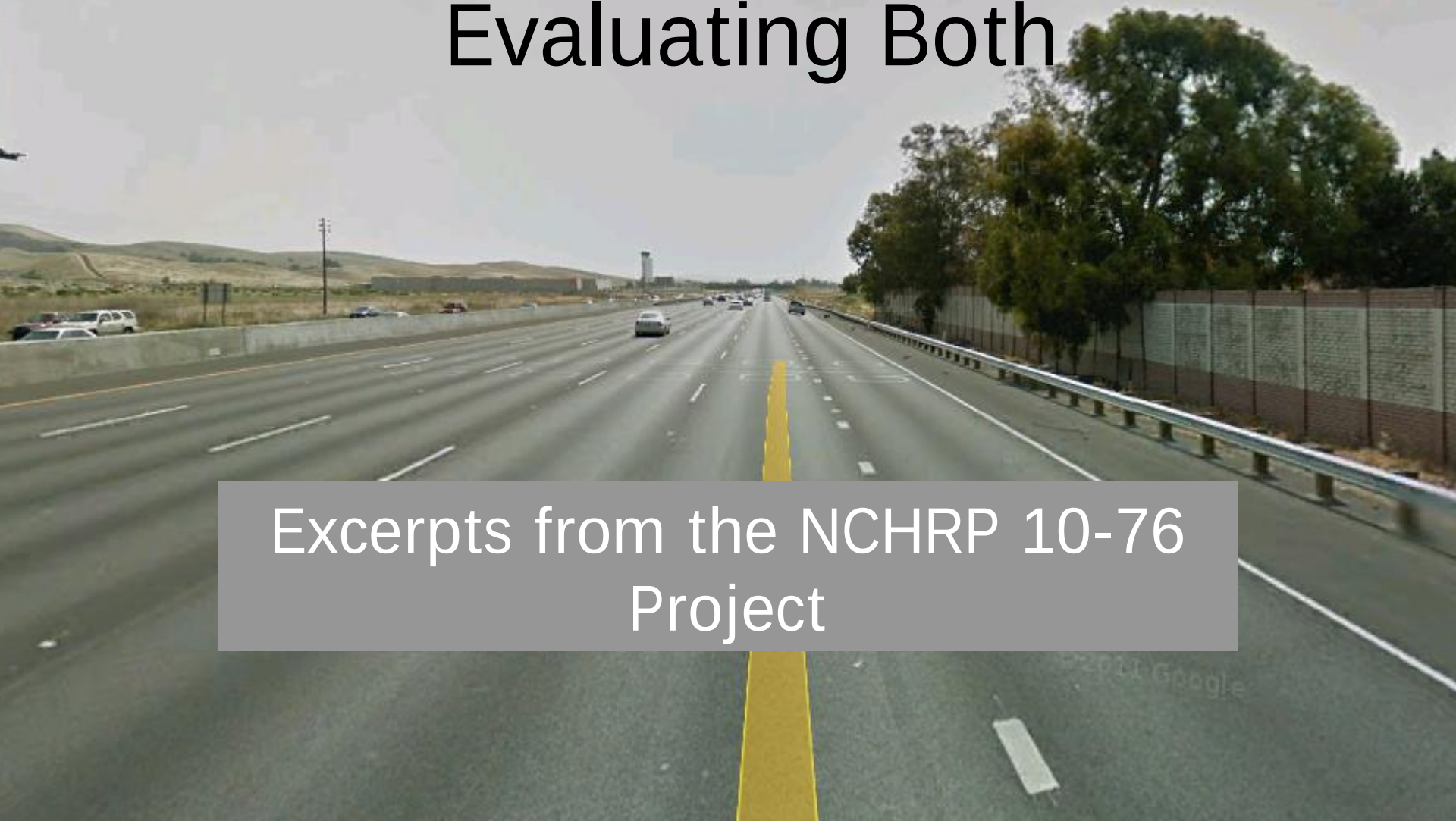


Barriers & Quieter Pavement Together: Methodologies for Evaluating Both

Excerpts from the NCHRP 10-76
Project



Acknowledgements

Team Members:

- Judy Rochat – Volpe Center
- Linda Pierce – Applied Pavement Technologies
- Harvey Knauer – Environmental Acoustics, Inc.
- Dana Lodico – Lodico Acoustics, LLC
- Paul Donovan (PI) – I&R

State Agencies:

- Greg Smith & Joe Rauseo – NCDOT
- Bruce Rymer & Jim Andrews – Caltrans
- Fred Garcia – ADOT
- Ryan McNeill – MassDOT

NCHRP:

- Amir Hanna

NCHRP 10-76 Objective

Develop & Demonstrate Methodologies
for Evaluating Pavement Strategies &
Barriers Together for:

- Feasibility
- Reasonableness
- Effectiveness
- Acoustic Longevity
- Economic Features

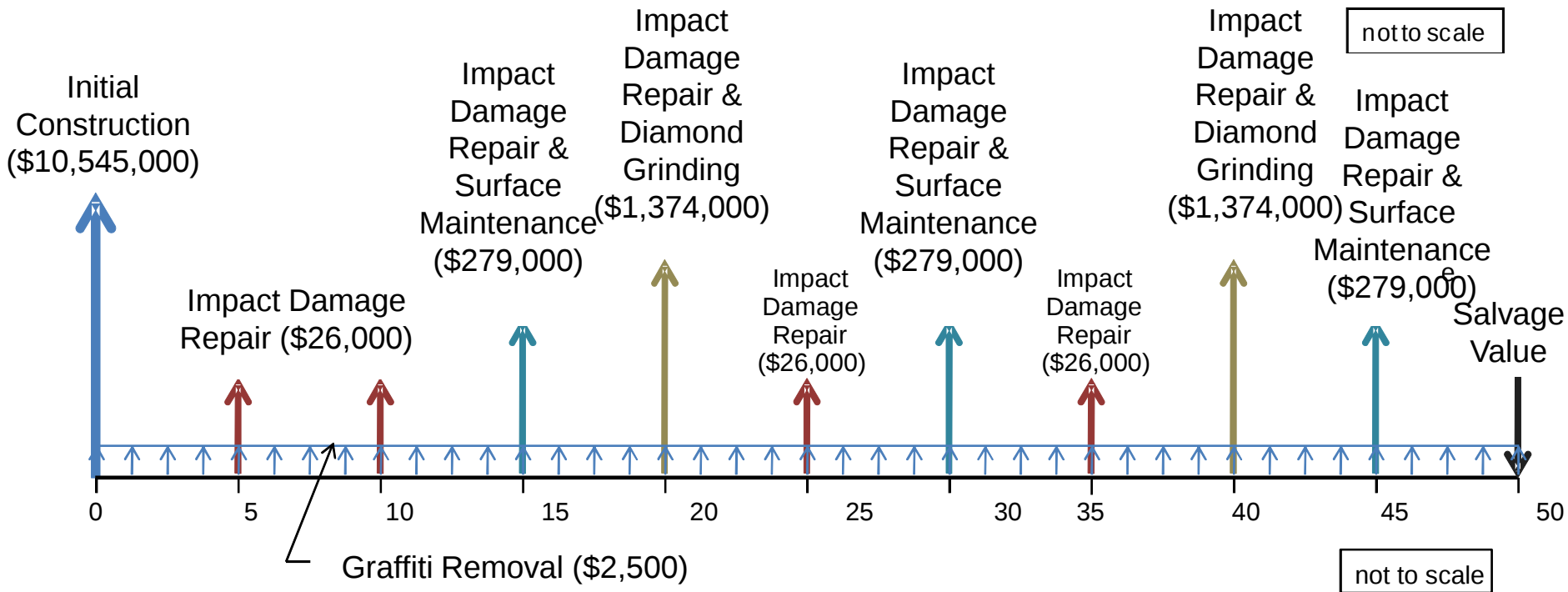
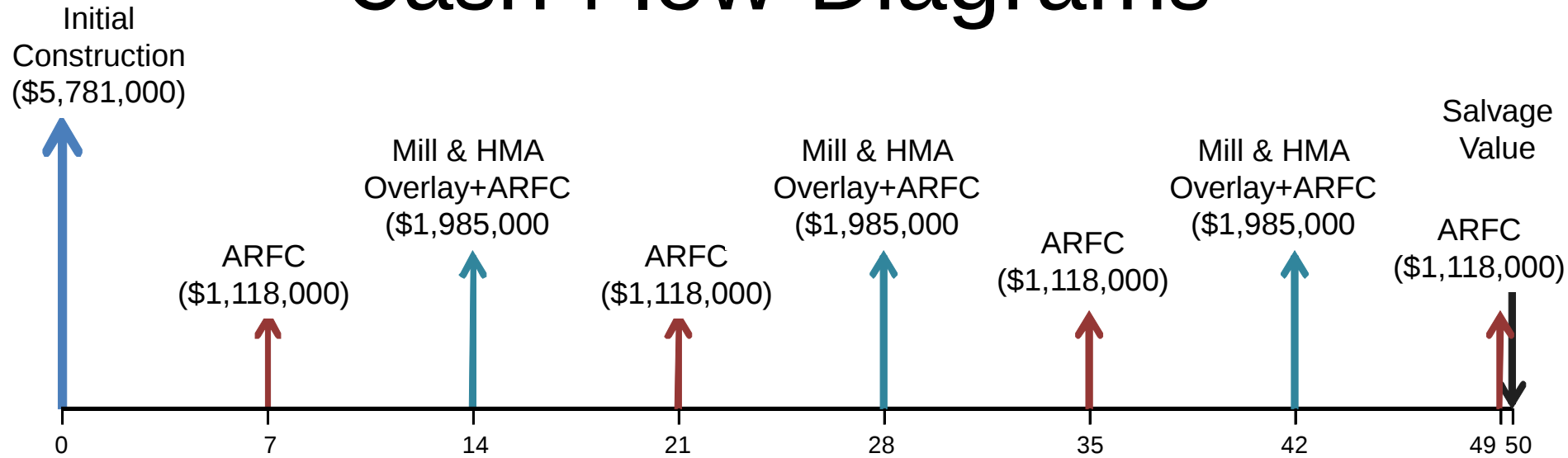
Ingredients

- NCHRP 1-44 demonstrated correlation between OBSI and SPB for cars and trucks
- FHWA Pavement Implementation Study developed modification of the “GLSS” with OBSI data to account for tire/pavement noise differences
- FHWA LCCA expanded to include initial and lifetime costs of barriers

Life Cycle Cost Analysis

- Currently a tool recommended by FHWA for LCCA of pavements
- Accounts for initial costs and ongoing rehabilitation and maintenance costs
- For noise abatement, can account for:
 - Barrier initial cost and maintenance
 - Pavement initial cost and costs for accelerated rehabilitation to maintain acoustic performance
- Demonstration cases using 6-lane new highway construction

Cash Flow Diagrams



Resultant Costs

Total Cost	Alternative 1: HMA (7-year overlay cycle)		Alternative 2: PCC (with 12 ft sound wall)	
	Agency Cost (in \$1000)	User Cost (in \$1000)	Agency Cost (in \$1000)	User Cost (in \$1000)
Undiscounted Sum	\$15,249.71	\$66.34	\$14,334.00	\$31.47
Salvage Value	\$958.29	\$9.53	\$0	\$0
Present Value	\$9,623.79	\$24.81	\$11,846.04	\$9.88
EUAC	\$447.99	\$1.15	\$551.44	\$0.46

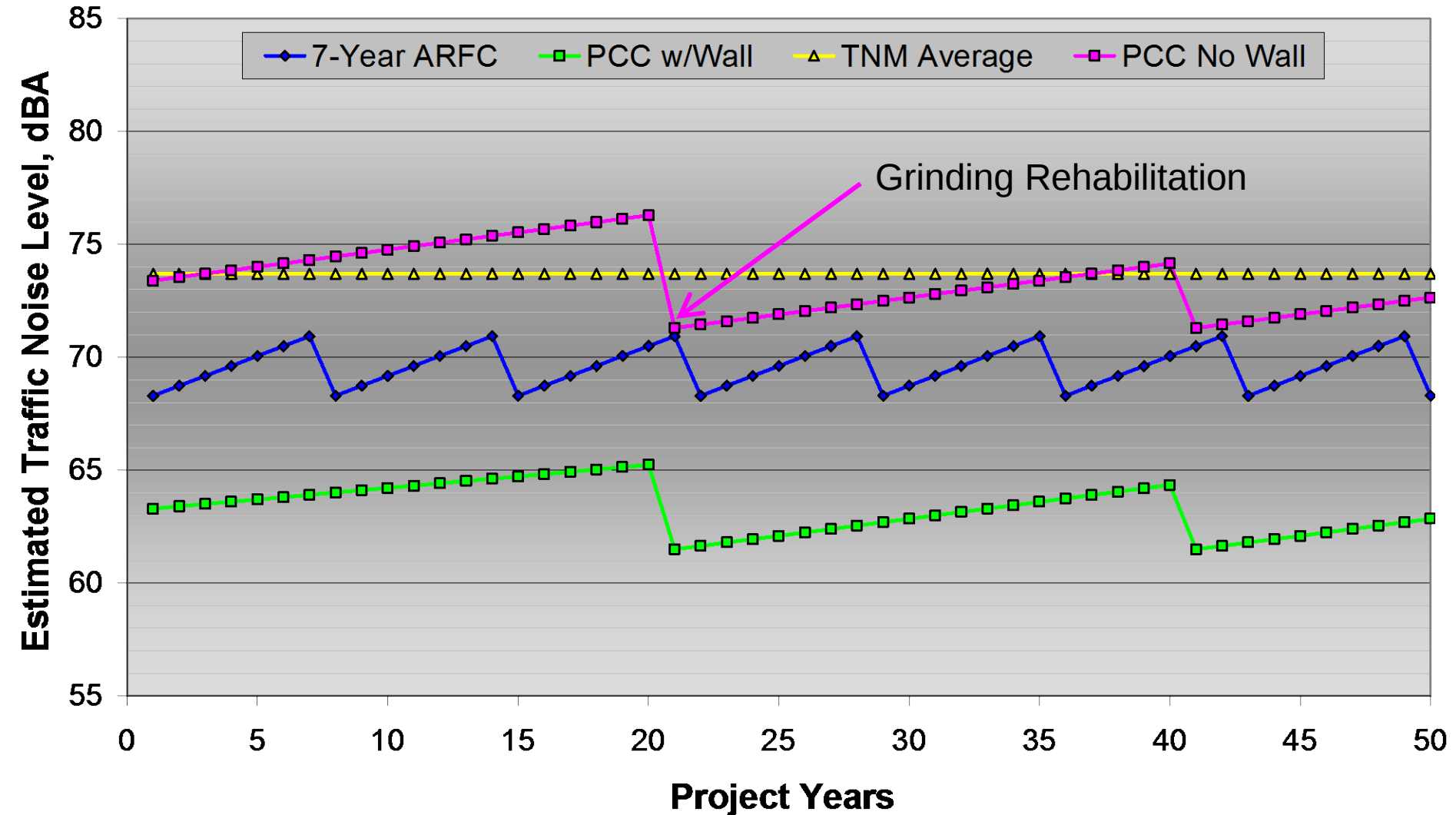
- For life cycle cost, consider the Present Value or the Equivalent Uniform Annual Cost
- LCC is highly dependent on the length of the rehabilitation cycle

Life Cycle Noise Performance

Pavement Description	OBSI Levels for New & Aged Pavement			
	Pavement Age			
	New	7 years	8 Years	20 years
RAC(O) from LA 138	96.0	99.3	99.7	
DGAC from LA 138	99.8	101.9	102.2	
OGAC 75mm from LA 138	95.6	99.3	99.8	
OGAC 30mm from LA 139	96.3	100.0	100.6	
ARFC from ADOT QPPP	94.4	99.4	100.0	
Long. Tine PC from Mojave	102.4	103.5	103.7	105.1
Ground PCC from Mojave	99.6	101.4	101.6	
Rand. Trans Tine PCC from Ohio			108.6	
Semi-Uniform Trans Tine from NC			105.2	
Ground PCC from NC			101.6	
S9.5 HMA from NC	98.7			

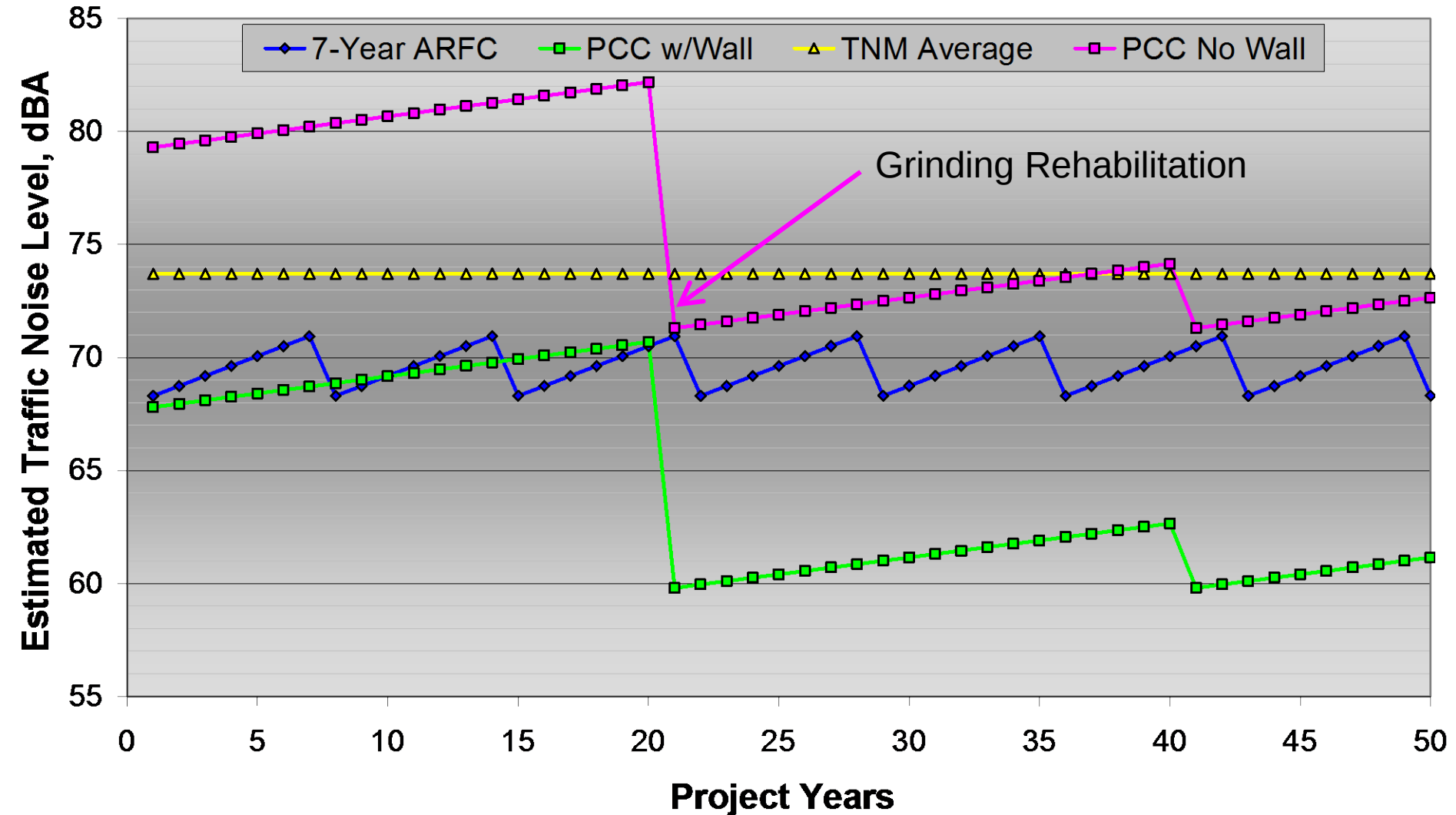
Acoustic Life Cycle

(Longitudinal Time PCC)



Acoustic Life Cycle

(Random Transverse Tine PCC)



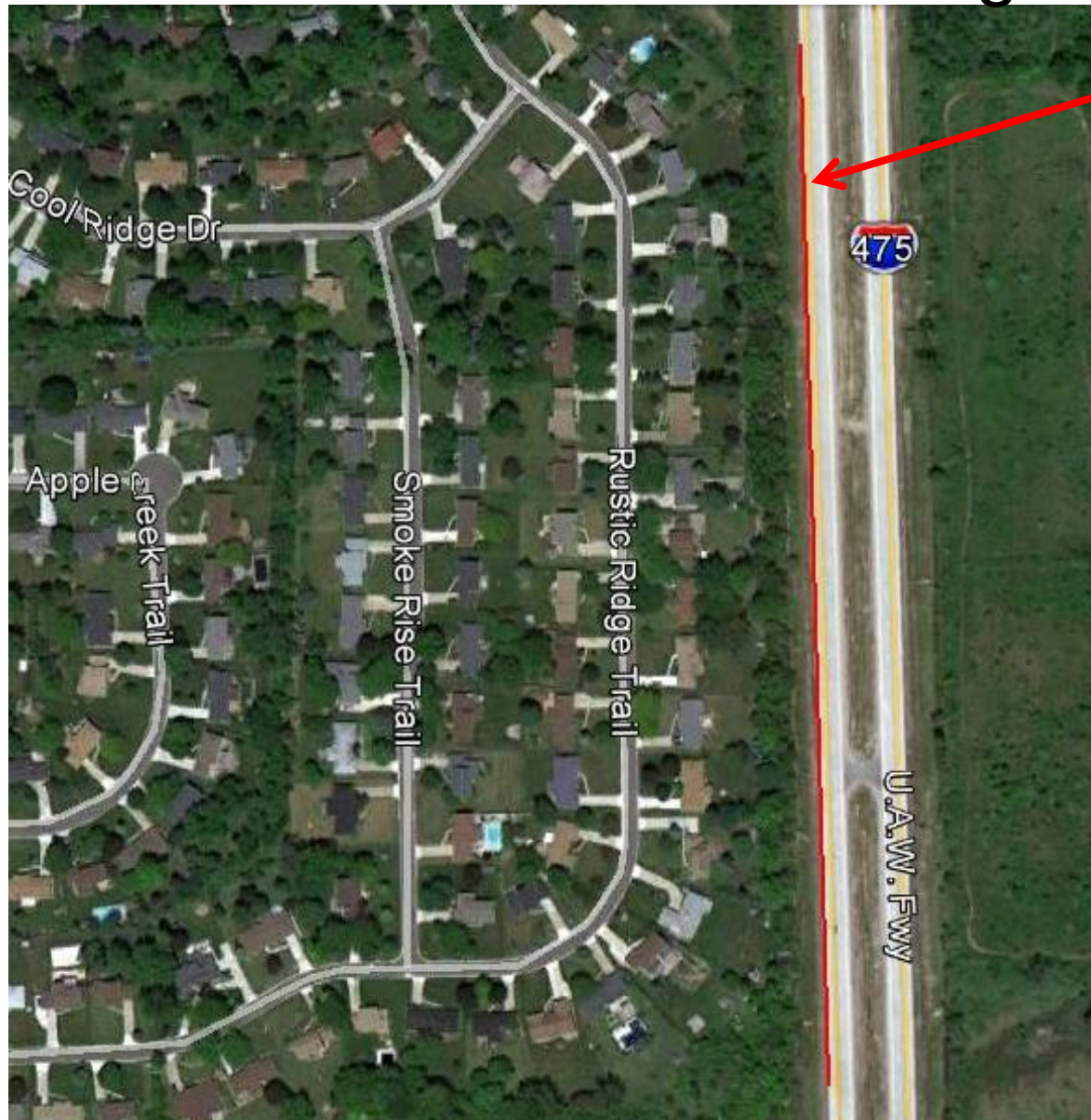
Garden Grove, CA

High Density Example Case



Low Residential Density

I-475 Grand Blanc in Michigan

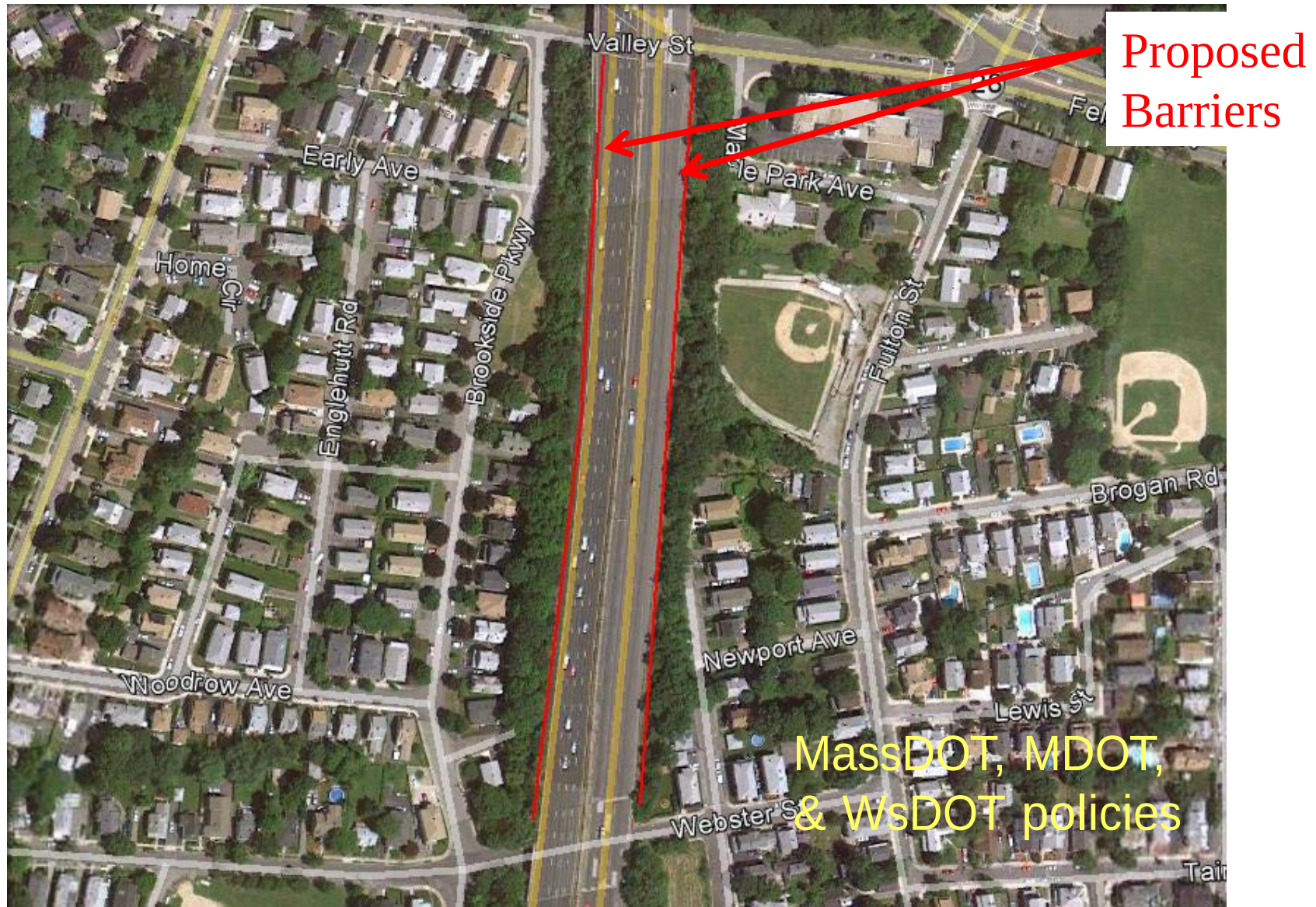


Proposed
Barrier

MDOT,
Caltrans, &
WsDOT
policies

Suburban Case, Dual Barriers

I-93 Medford in Massachusetts



Case History Examples

- California
 - I-580 lane addition near Livermore
 - Three segments, 10 barriers
 - New & existing barriers
- North Carolina
 - I-40 near Raleigh & I-485 near Charlotte widening
 - 4 new barriers total
- Arizona
 - New highway project
 - Highway realignment project

I-580 Segment 3 at Livermore, CA



I-580 Lane Addition

Concrete Options:

- Texture similar to existing lanes
- Grind all lanes
- Overlay all lanes with RAC(O)

HMA Option:

- Overlay all lanes with RAC(O)
- Construction of HMA alone greater than PCC!!

I-580 Barrier Cases for Segment 3

Designation	Current Height (ft)	Proposed Height (ft)		Length (ft)	# of Impacted Receptors
		LT PCC	Grd PCC/ RAC(O)		
SWWB10	0	12	12	800	4
SWWB11	0	14	12	900	13
SWEB11	0	12	12	900	16

I-580 Barrier SWWB10

Pavement Type and Barrier Height	Number Benefited	Predicted Level Range, dBA	Noise Reduction Range, dB	Total Project NPV (\$1000)	NVP for Noise Abatement (\$1000)	Reasonableness Allowance (\$1000)	Feasible	Cost Reasonable	Design Reasonable	Effectiveness, dB
PCC No Additions	0	68-77	0	559	-	-				13
PCC + 12 ft	3	66-68	2-9	1,113	554	165	Y	N	Y	4
PCC + Grd	0	65-74	3	767	207	-	N	N	N	10
PCC + Grd + 12 ft	4	63-67	5-10	1,321	761	220	Y	N	Y	3
PCC + RAC(O)	4	62-71	6	707	148	220	Y	Y	N	7
PCC + RAC(O) + 12 ft	4	62-64	5-13	1,261	632	220	Y	N	Y	0

I-580 Barrier SWWB11

Pavement Type and Barrier Height	Number Benefited	Predicted Level Range, dBA	Noise Reduction Range, dB	Total Project NPV (\$1000)	NVP for Noise Abatement (\$1000)	Reasonableness Allowance (\$1000)	Feasible	Cost Reasonable	Design Reasonable	Effectiveness, dB
PCC No Additions	0	64-78	0	629	-	-				9
PCC + 14 ft	3	61-70	3-8	1,356	727	165	Y	N	Y	3
PCC + Grd	0	62-75	2-3	863	233	-	N	N	N	8
PCC + Grd + 12 ft	20	59-68	4-10	1,486	857	1,100	Y	Y	Y	1
PCC + RAC(O)	0	61-74	2-4	796	167	-	N	N	N	7
PCC + RAC(O) + 12 ft	20	59-67	4-11	1,419	790	1,100	Y	Y	Y	0

I-580 Barrier SWEB11

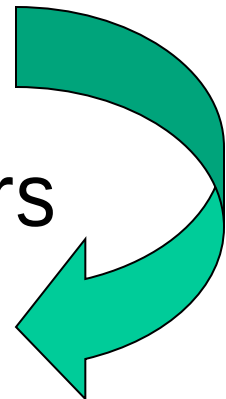
Pavement Type and Barrier Height	Number Benefited	Predicted Level Range, dBA	Noise Reduction Range, dB	Total Project NPV (\$1000)	NVP for Noise Abatement (\$1000)	Reasonableness Allowance (\$1000)	Feasible	Cost Reasonable	Design Reasonable	Effectiveness, dB
PCC No Additions	0	69-81	0	629	-	-				12
PCC + 12 ft	10	66-71	3-10	1,252	623	550	Y	N	Y	2
PCC + Grd	0	67-73	2	863	233	-	N	N	N	10
PCC + Grd + 12 ft	16	64-69	5-12	1,486	857	880	Y	Y	Y	0
PCC + RAC(O)	6	65-76	4-5	796	167	338	Y	Y	N	7
PCC + RAC(O) + 12 ft	16	62-69	7-12	1,419	790	880	Y	Y	Y	0

I-580 Segment 3 at Livermore, CA



Hybrid Approach to Benefit Receptors behind Proposed SWWB10

- Apply RAC(O) to all of segment (2,275 Ft)
- Added NPV Cost of pavement - \$421,000
- Build Barriers SWWB11 & SWEB11 for NPV cost of \$1,246,000
- Total NPV cost - \$1,685,000
- Adds 4 more benefited receptors
- New allowance is \$2,200,000



North Carolina I-40 Lane Addition



I-40 Lane Addition

Concrete Option (Only)

- Add lane, texture to match existing transverse pavement
- Add lane, grind all lanes
- Add lane, overlay with S9.5 mm HMA

Interstate 40



I-40 Lane Addition Alternatives

Pavement Costs

Alternative		Agency Cost (\$1000)
No.	Description	
1	Added PCC Lane Only	4,186
2	Added PCC Lane - All Lanes Ground	5,427
3	Added PCC Lane - S9.5 HMA) Overlay	5,942

Pavement & Barrier Designs

Designation	Current Height (ft)	Proposed Height (ft)		Length (ft)	# of Impacted Receptors
		Transverse Tine PCC	Grd PCC/ RAC(O)		
NSA02 SB	0	14 & 16	12	1,553	43
NSA02 NB	0	14 & 16	12	3,738	52

I-40 Southbound Barrier

Pavement Type and Barrier Height	Number Benefited	Predicted Level Max & Avg, dBA	Noise Reduction Range, dB	Total Project NPV (\$1000)	NVP for Noise Abatement (\$1000)	Reasonableness Allowance (\$1000)	Feasible	Cost Reasonable	Design Reasonable	Effectiveness, dB
PCC No Additions	0	77/67	0	1,231	-	-				9
PCC + 14 ft	21	74/64	3-9	2,082	851	810	Y	N	Y	6
PCC + 16 ft	29	74/63	4-11	2,203	972	1,110	Y	Y	Y	6
PCC + Grd	0	74/64	3	1,596	365	-	N	N	N	6
PCC + Grd + 12 ft	38	71/62	5-10	2,325	1,094	1,448	Y	Y	Y	3
PCC + S9.5 HMA	35	71/62	4-6	1,747	516	1,335	Y	Y	N	3
PCC + S9.5 HMA + 12 ft	70	68/60	7-12	2,476	1,245	2,648	Y	Y	Y	0

Cheapest, least effective, & fewest benefited receptors

Most expensive, most effective, & most benefited receptors

I-40 Northbound Barrier

Pavement Type and Barrier Height	Number Benefited	Predicted Level Max & Avg, dBA	Noise Reduction Range, dB	Total Project NPV (\$1000)	NVP for Noise Abatement (\$1000)	Reasonableness Allowance (\$1000)	Feasible	Cost Reasonable	Design Reasonable	Effectiveness, dB
PCC No Additions	0	76/66	0	2,962	-	-				11
PCC + 14 ft	51	70/61	5-10	5,010	2,048	1,940	Y	N	Y	5
PCC + 16 ft	62	70/60	5-11	5,303	2,340	2,352	Y	Y	Y	5
PCC + Grd	0	73/64	2-3	3,841	878	-	N	N	N	8
PCC + Grd + 12 ft	90	68/59	7-11	5,596	2,633	3,402	Y	Y	Y	3
PCC + S9.5 HMA	33	70/61	4-5	4,205	1,243	1,265	Y	Y	N	5
PCC + S9.5 HMA + 12 ft	98	65/58	8-12	5,960	2,998	3,702	Y	Y	Y	0

Cheapest, least effective, & fewest benefited receptors

Most expensive, most effective, & most benefited receptors

Further Considerations for I-40 Alternative Selection

- Separate pavement & barrier costs
- Apply quieter pavement for length of longest barrier
- Re-total abatement NPV costs

	Abatement NPV Costs (\$1000)			Benefited Receptors		
	PPC	Grd PCC	S9.5	PPC	Grd PCC	S9.5
Pavement	-	878	1,243			
Barrier NSA02 SB	972	729	729	29	38	70
Barrier NSA02 NB	2,340	1,755	1,755	62	90	98
Total	3,312	3,362	3,727	91	128	168
Cost/Benefited Receptor	36	26	22			

Remarks

- This research is directed at methodology not policy
- No general conclusions about different abatement methods or pavements should be made from this research
- There appears to be benefit and rationality of considering barriers & pavement together
- The methodology could be applied immediately on a trial basis
- *Effectiveness* is key, new concept for evaluating barriers and pavement strategies