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Report
Effect of Natural Cleaning on Salt Deposition on Queensland Bridges

Research Project No: 2005-003-B-07

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1 INTRODUCTION

Maintenance of bridge structures is a major issue for the Queensland Department of Main Roads. In the previous phase of this CRC project an initial approach was made towards the development of a program for lifetime prediction of metallic bridge components. This involved the analysis of five representative bridge structures with respect to salt deposition (a major contributor to metallic corrosion) to determine common elements to be used as “cases” - those defined for buildings are not applicable.

The five bridges analysed included the Gladstone Port Access Road Overpass, Stewart Road Overpass, South Johnstone River Bridge, Johnson Creek Bridge and the Ward River Bridge. The locations of these bridges are shown in Figure 1.

Figure 1 Locations of the five bridges analysed

1.1 Analysis Methodology

The salt deposition on the five representative bridge structures was computed using computational fluid dynamics (CFD) and compared against the deposition on a salt candle at the same location.

Illustrative results for the Gladstone Port Access Road Overpass are shown. The Gladstone Port Access Road Overpass in Gladstone City is located at latitude 23°51’ and longitude 151°30’. It is on the Gladstone Port Access Road between Glenlyon Road and the Port Precinct and passes over the top of Auckland Street and the railway lines. There is ocean to the North, North East and East of this bridge.

The bridge comprises twelve spans ranging in length from 28.4 metres to 37 metres. The superstructure consists of a reinforced concrete deck on rectangular prestressed concrete deck units for span 12 and on five T-ROFF trough-shaped prestressed concrete girders for spans 1 to 11. For these 11 spans the total width of the superstructure is 10.44 metres and the height is 2.81 metres, giving a height to width ratio of 1:3.7.

The salt deposition on a salt candle, extracted from the CSIRO GIS database at the location of Gladstone for a marine environment at the latitude and longitude given, is 13.3 mg.m^2/day. This does not take into account the bridge height.

The deposition on the superstructure was checked using three different aerosol release strategies. In one, aerosols were released directly upwind of the bridge, in the second they were released in bands above and below the bridge, in the third they were released over a broad area. Results for the Gladstone overpass are shown in Figure 2. The aerosol was diffused upstream due to turbulence.

Salt becomes trapped in the recirculation regions between the bridge girders, but although the concentration of the salt in the air between the girders is high, little is deposited on the girders and the underside of the deck.

The salt deposition on the bridge structure is summarized in Figure 3. The deposition is largest on upwind faces, intermediate on horizontal faces and least on downwind faces and in protected parts of the under bridge deck. The highest deposition rates are found on the bottom edges of the two downwind girders and on the upwind face of the upwind face of the upwind parapet.

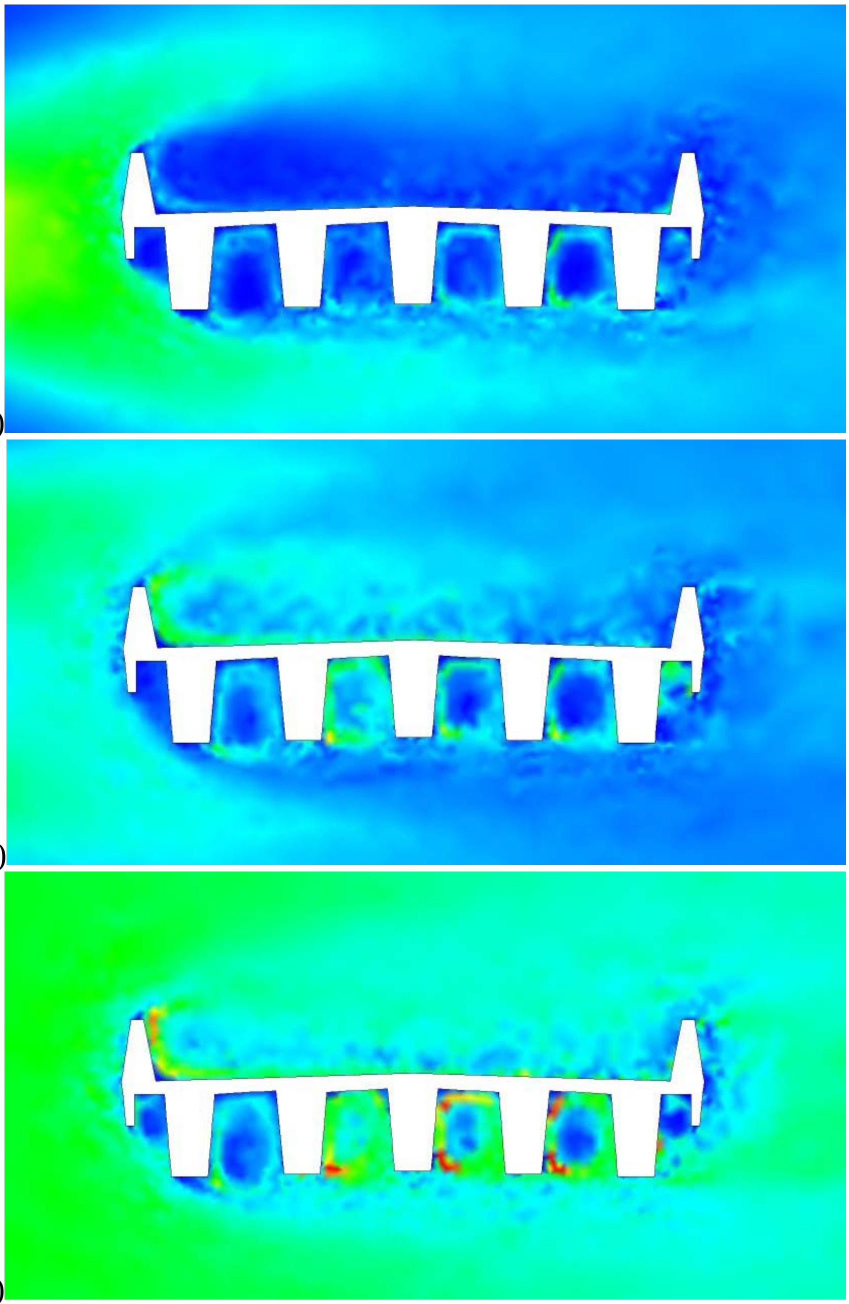
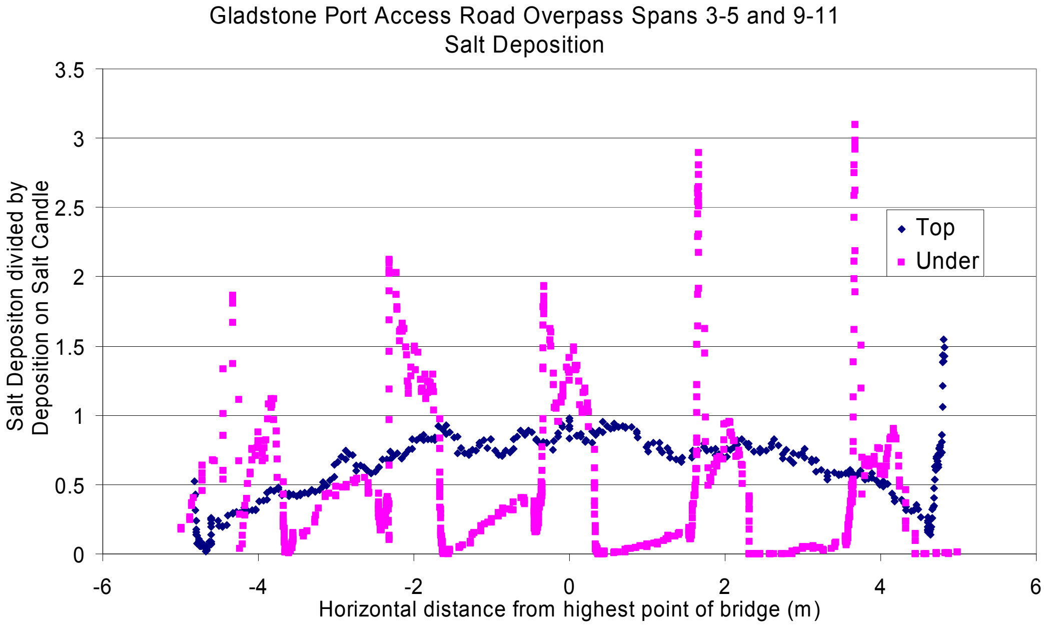
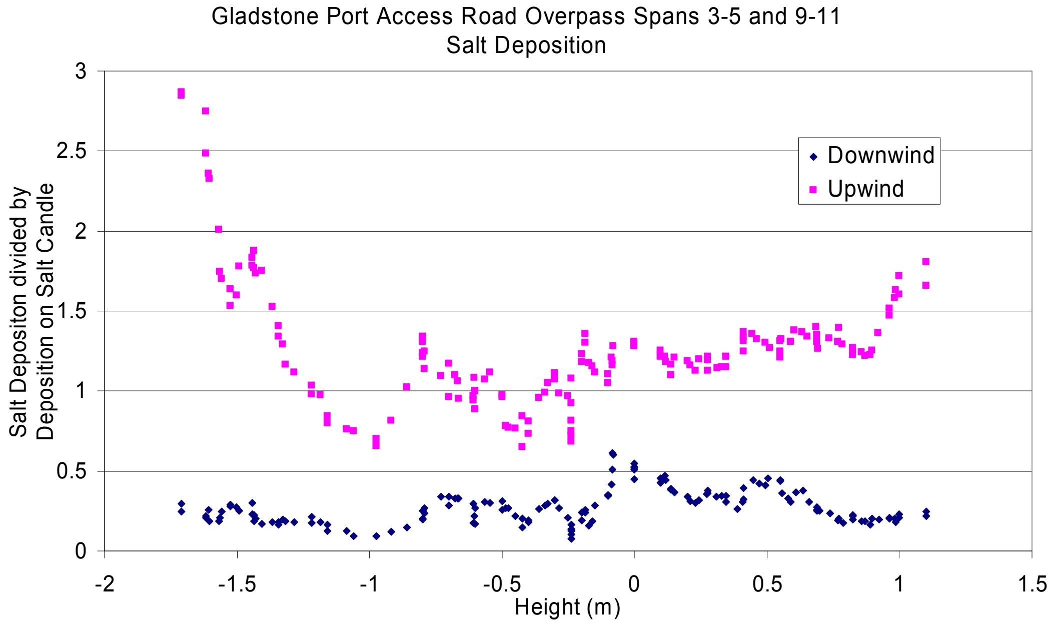


Figure 2 Volume fraction of salt around the superstructure of the Gladstone Port Access Road Overpass; a) particles released within 1.4 metres of the mid-height, b) particles were released between 1.4 and 2.8 metres of mid-height, c) all salt aerosol particles. Flow is from left to right. Red is high concentration and blue is low concentration



a)

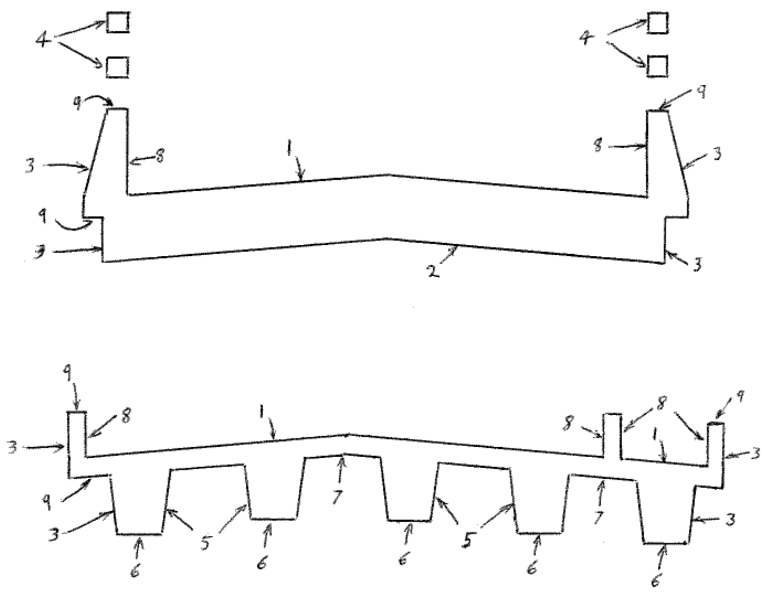


b)

Figure 3. Salt deposition on the Gladstone Port Access Road overpass measured relative to the salt candle deposition

1.2 Bridge Zones

For the comparison of different bridge superstructures, results were averaged over a set of physical locations (zones) on each bridge. These zones are shown for two typical bridge cross sections in Figure 44.



1.Road surface and median strip
2. Bridge undersurface
3. Side face
4. Handrails
5. Side of support beams
6.Undersurface of support beams
7. Protected undersurface
8. Lane divider and inside the parapet
9. On top of the parapet and under the side overhang

If the support beams are closer than 100 mm apart then "2" applies instead of "5, 6 and 7".

Figure 4 The layout of zones on two typical bridge cross sections.

For the purposes of this work the various zones are assumed to be constructed from the following materials:

Zone 1 – Road surface	Painted concrete
Zone 2 – Under surface	Bare concrete, rough finish
Zone 3 – Side face	Bare concrete, smooth finish
Zone 4 – handrails	Bare metal, uncorroded
Zone 5 – side of support beams	Bare concrete, rough finish
Zone 6 – under surface of support beams	Bare concrete, rough finish
Zone 7 – Protected undersurface	Bare concrete, rough finish
Zone 8 – Lane divider, inside parapet	Bare concrete, smooth finish
Zone 9 – Top of parapet, under overhang	Bare concrete, smooth finish

1.3 Other Factors Affecting Salt Levels

In report No2 the effect of bridge height above water level on the salt deposition rate was considered. Apart from very close to the coast, the height does not have a large effect on the salt deposition levels. Of course, all the salt that is deposited on a structure does not necessarily remain there. Natural occurrences, in particular rain, may remove some of the deposited salt. The rate at which this occurs will depend on the amount of the rain, the material of the structure, the orientation and natural sheltering. This report looks at the natural cleaning of the bridge components already defined and combines this with rainfall data for Queensland to give a revised value for salt deposition for the bridge zones taking into account the amount removed by rain. Rainfall varies significantly across the state of Queensland (see Figure 5)

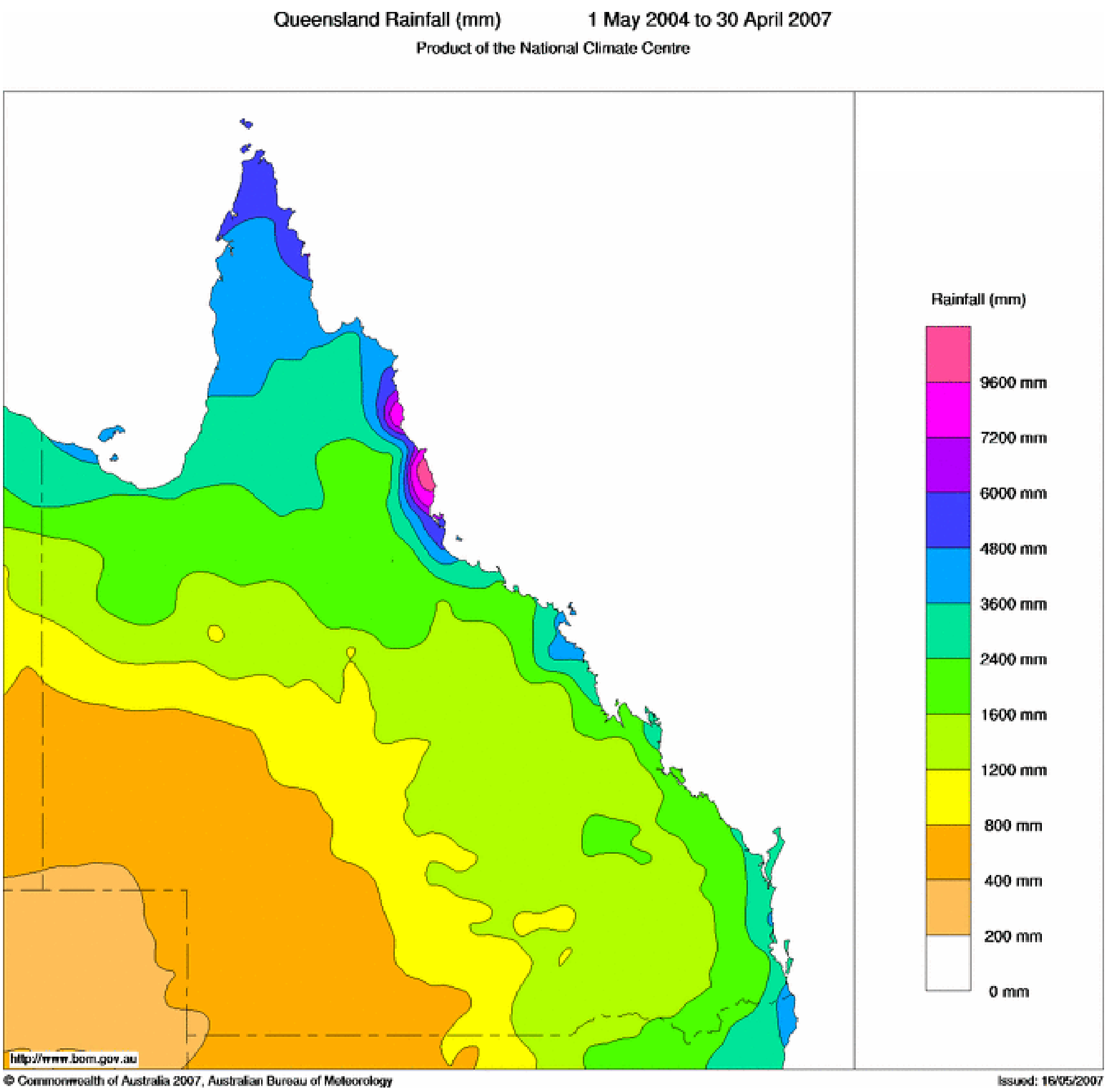


Figure 5. Bureau of Meteorology data on Queensland rainfall

2 NATURAL CLEANING OF BRIDGE COMPONENTS

2.1 Minor mechanisms

Wind and condensation do little to clean bridges.

A study of salt removal by the wind showed that this can only happen if the salt aerosol is deposited completely dry and has not become wet at any time before the strong wind, and even then the wind is unlikely to dislodge many particles.(Muster and Cole, 2005; Cole at al., 2004)

A study of condensation on surfaces has shown that the water condensed on the surfaces soaks onto or into those surfaces, resulting in stronger contact between the salt and the surfaces and possibly leading to more corrosion rather than less.

2.2 Locations washed by rain

Results of computer simulations of rain falling on bridge superstructures are shown in Figure 6. 50,000 raindrops with a mean diameter of 2.1 mm (terminal velocity 6.7 m/s) in a rain-shower of intensity 15.7 mm/hr were released above the bridges. The assumed wind speed is 4.4 m/s at the Gladstone Overpass and 4.0 m/s at Ward River) The size distribution of raindrops was "Best's raindrop distribution" as reported in Seinfeld & Pandis (1998). This is equivalent to a Rosin-Rammler distribution with size 2.48 mm and power 2.25.

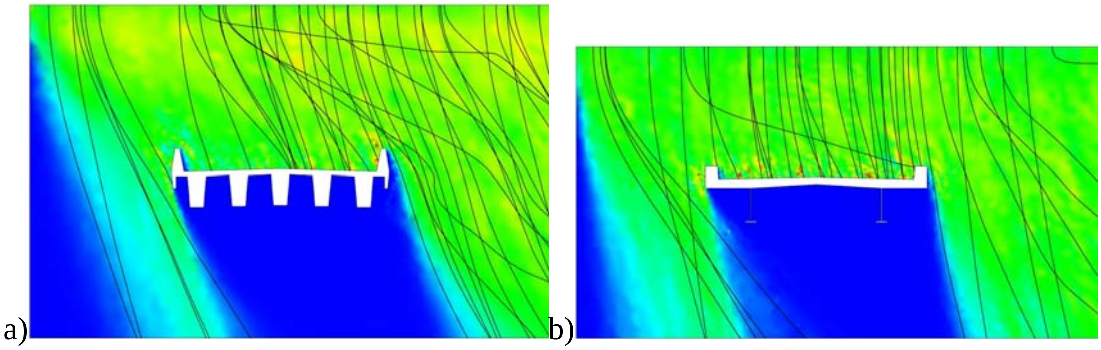


Figure 6. Rainfall on the bridges at a) Gladstone Port Overpass , b) Ward River. The colours represent rainfall intensity, with blue as low intensity and red as high intensity (rain coming in through the left boundary has been ignored). The black lines are tracks of individual raindrops.

Simulations of rain falling on bridges behaved as expected. The bridge components that are oriented upwards and outwards on the sides of the bridge get very wet when the rainfall is heavy enough. The bridge components under the bridge superstructure, and those on the side of the bridge opposite where the rain is coming from can get slightly damp, but not enough for rain-washing. Figure 4 shows the zones previously identified for aerosol deposition and applied to the Ward River Bridge in Figure 7..

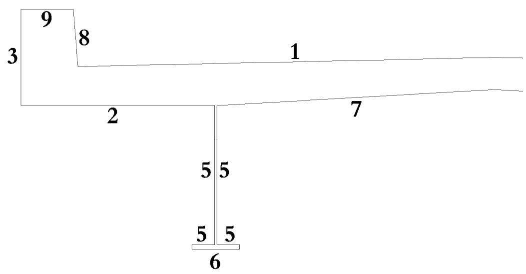


Figure 7. Zones on the bridge at Ward River.

The direction from which the rain comes results from a combination of the wind due to synoptic pressure systems (highs and lows) and wind generated by the rainstorm itself. The heavier the rain, the more the wind is generated by the rainstorm and the more this governs the wind direction. The wind generated by the rainstorm can be in any direction so it is reasonable to say that cleaning by rain can occur on all sides of the structure.

There are locations on the superstructure where the rain drips off. These areas are very prone to corrosion, salt can build up there and the longer than normal presence of water makes it a very corrosive micro-environment. This applies particularly to zone 6 of the Ward River Bridge, and the bottom edges of handrail and crash barrier components on other bridges.

The parts of the piers under the centre of the superstructure are shielded from the rain and so the salt is not cleaned off there. The surfaces of the piers under the edges of the superstructure are cleaned by rain. To account for the different effects of rain a factor η is introduced where the actual rain impacting on a surface is simply η multiplied by the measured rainfall. Thus for fully exposed positions, such as the road surface and top of the parapet, $\eta = 1$, for positions, such as the side face, some rain which is off the vertical is blocked by the opposite side of the parapet and so $\eta = 0.8$. In the case of the hand rails, the undersurface is taken as this is the worst case. Here rain impact will be limited but there will be some run off effect from the top of the rail so $\eta=0.3$. For the side position of the support beams, limited rain deposition will occur in high winds when the rain is at an acute angle to the vertical. These factors are summarised in Table 1.

Table 1. Values derived for η (rainfall reduction factor)

No	Element	η	Reasoning
1	Road Surface	1	Fully exposed
2	Bridge Underside	0	Fully sheltered
3	Side face	0.8	Some sheltering
4	Hand rails	0.3	Underside taken as worst case
5	Side of Support Beams	0.05	Very limited rain deposition
6	Undersurface of support beams	0	Fully sheltered
7	Protected undersurface	0	Fully sheltered
8	Lane divider and inside the parapet	0.8	Some sheltering
9	On top of the parapet and under the side overhang	1	Fully exposed

2.3 Rainfall intensity and duration needed for bridge cleaning

Not all the rain falling on a structure runs off. Some adheres to the surface and some soaks into the surface. This can be treated on individual surfaces as an initial loss ϕ_i (in mm) and a continuing loss ϕ_c(in mm/hr). If the rainfall rate is R in mm/hr then the runoff ϕ_o(t) is given by:

$$\phi_o(t) = \max(0, (R - \phi_c)t - \phi_i). \quad \text{.... Eqn (1)}$$

Tests conducted at CSIRO gave the following measured values for ϕ_c and ϕ_i.

Painted concrete (painted steel would be similar):

$\phi_c = 0$; $\phi_i \approx 0.04$ mm

Bare metal, uncorroded:

$\phi_c = 0$; $\phi_i = 0.17$ mm

Bare concrete, smooth finish:

$\phi_c = 0.96$ mm/hr; $\phi_i = 0.092$ mm;

Bare concrete, rough finish (eg. from formwork made from old softwood planks)

$\phi_c \approx$ 1.1 mm/hr; ϕ_i = 0.31 mm

As an example, suppose rain fell at a rate of 5 mm/hr on smooth bare concrete for a period of 10 minutes. Then the runoff would be (using Eqn 1):

ϕ_o = max(0,(5-0.96)(10/60) – 0.092) = 0.58 mm

This would be enough to wash the surface.

The above analysis was conducted for a short rain storm. Unfortunately rain fall data is not available at this level of detail and is generally only available on a three hour interval. Thus the amount of rain run off has been recalculated for 3 hour rain periods. This data has been calculated for Brisbane where a set of data with rain intervals of one minute are avaliable. This is shown in Table 2. Given this data new rain washing factors were calculated.

Table 2. Run off calculations using Brisbane rainfall

Rainfall	Runoff (mm)				Duration of Runoff (min)	
3hr_rain(mm)	Painted	Bare Metal	Smooth Concrete	Rough Concrete	General	Rough Concrete
122.2	120.9	118.7	117.5	116.2	157	147
60.7	59.9	58.5	58.1	57.0	82	72
37.4	36.3	33.8	34.1	30.9	73	51
24.3	23.1	20.0	20.9	16.9	61	32
17.0	15.9	13.0	13.9	10.3	50	25
12.1	11.1	8.4	9.4	6.3	39	15
6.9	6.1	3.9	4.8	2.5	26	7
3.6	3.0	1.5	2.2	0.7	15	3
1.7	1.4	0.6	1.0	0.2	8	1
0.8	0.6	0.2	0.4	0.0	4	0
0.2	0.2	0.0	0.1	0.0	1	0

From this data the parameters ϕ_{3c}, ϕ_{3l} have been evaluated for the given surfaces and shown in Table 3 (here the suffix 3 represent data relevant to three hour rainfall data).

Table 3. Runoff parameters for various surfaces

	Runoff (mm)			
Parameter	Painted	Bare Metal	Smooth Concrete	Rough Concrete
ϕ_{3c}	0	0.43	0.61	1.2
ϕ_{3l}	0.04	0.17	0.09	0.31

2.4 Relationship Between Runoff and Cleaning

In previous work relating to the holistic model of corrosion, the effect of rain on cleaning a fresh plate has been approximated, to the first order, by (Cole at al, 2007)

$S_f = S_i \times e^{-\alpha R}$ if $R_i - R_c > 0$ Eqn (3)

or

$S_f = S_i$ if $R_i – R_c < 0$ Eqn (4)

Where S_i is the initial salt content and S_f is the final salt content (after rainfall), R_i is the rainfall rate (in mm/hr) in a particular rainfall event and R_c is the critical rainfall rate (in mm/hr) required to guarantee runoff and cleaning.

In experimental studies it was found that runoff is not even, with individual drops needing to coalesce to reach a critical size before running down the plate and cleaning a path. Figure 8 shows the stepped shape of the pollution level curve due to this uneven cleaning. It can be approximated to an exponential decay rate.

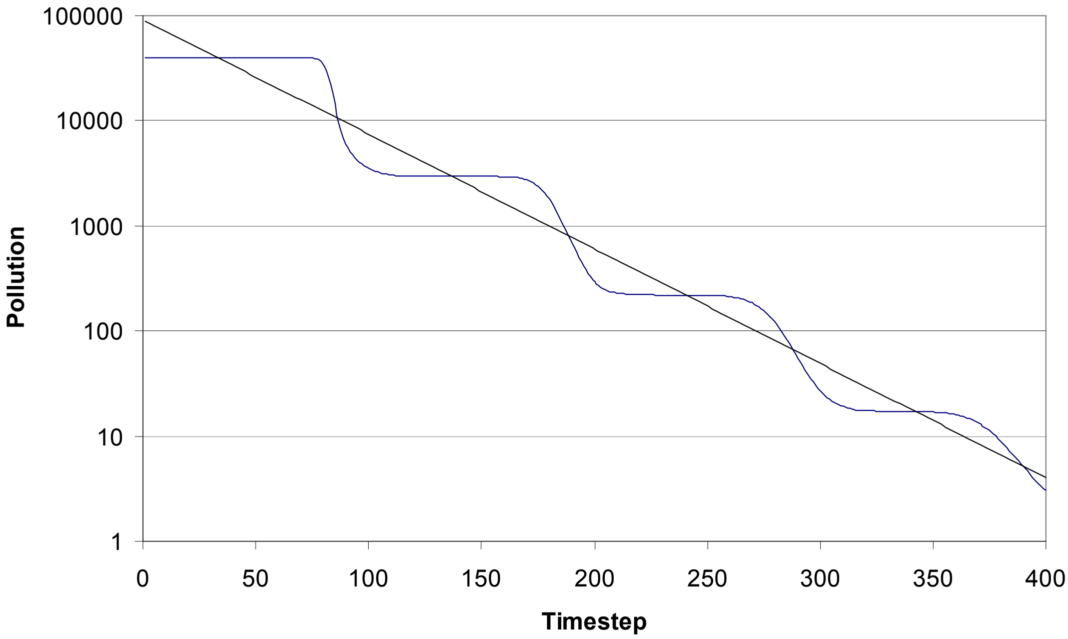


Figure 8 Pollution levels on the rain-washed part of the surface, together with a fitted exponential decay rate.

Depending on the rainfall rate, the size of the timestep will vary.

Equations 3 and 4 can be simplified if the run off is considered rather than the rainfall rate.

Then

$$S_f = S_i \times e^{-\alpha\phi} \quad \text{Eqn (5)}$$

Where ϕ is the run off given in Equation (1).

The current corrosion model considers three hourly intervals so in that time span the runoff is given by:

$$\phi_o(3) = \max(0, (\eta R - \phi_{3c}) - \phi_{3i}). \quad \text{Eqn (6)}$$

Where η is the geometric factor introduced that accounts for the different levels of rain falling on the component relative to rainfall onto a flat surface (see Table 1).

Thus the correct exponential decay factor is either 0 or $\alpha(\eta R - \phi_{3c}) - \phi_{3i})$, which thus has two terms $3\alpha\eta R - \alpha(\phi_{3c} + \phi_{3i})$ so we can simplify this as $\psi R - \phi$. So

$$S_f = S_i \times e^{-\psi R - \phi} \qquad \text{Eqn(7)}$$

3 MODIFIED BRIDGE PROGRAM

In the current form of the model, the salt deposition at the $i+1^{th}$ 3-hour interval is given by:

$$D_{i+1} = D_i \times e^{-\psi R - \phi} \qquad \text{Eqn(8)}$$

The parameters for the different components are given in Table 4.

Table 4. Parameter values for the different bridge components.

Element	Material	η	Ψ	Φ=α(Φ3C+Φ3i)
1.Road Surface	Painted concrete	1	1.5	0.06
2.Bridge Underside	Bare concrete Rough Finish	0	0	2.25
3. Side face	Bare Concrete – Smooth finish	0.8	1.2	1.050.
4.Hand rails	Bare metal -uncorroded	0.3	0.45	0.9
5.Side of Support Beams	Bare concrete Rough Finish	0.05	0.075	2.25
6.Undersurface of support beams	Bare concrete Rough Finish	0	0	2.25
7.Protected undersurface	Bare concrete Rough Finish	0	0	2.25
8. Lane divider and inside the parapet	Bare Concrete – Smooth finish	0.8	1.2	1.05
9. On top of the parapet and under the side overhang	Bare Concrete – Smooth finish	1	1.5	1.05

The bridge salt program does not have the ability to calculate directly the values of salt deposition or of salt retention. Rather it looks up values from Tables which have been precalculated using the Holistic Model. Thus in order to incorporate the effect of cleaning into the bridge model it is necessary to have parameters defining the effect of rain washing. An accumulated salt factor was introduced that incorporated the effects of rain and runoff in washing salt from the bridge structure in any particular location. Thus the formulae for accumulation of salt are:

- seasonal $(mg/m^2.season)$

$$accumulated\ salt_{seasonal} = \frac{D*90*A}{100} \qquad \text{Eqn(9)}$$

  - D - daily deposition rate in $mg/m^2.day$
  - A - accumulated salt factor in %

- annual ($mg/m^2.year$)

$$accumulated\ salt_{annual} = Minimum\left(SAL, \sum_{season=summer}^{spring} accumulated\ salt_{season}\right)$$

Eqn(10)

  - SAL - annual salinity at bridge location

Note that the annual accumulated salt cannot exceed the annual base salinity at the bridge location.

The holistic Model is then used to derive the parameter A. The value of A was derived for three different locations and 2 different levels of salinity. The Climate map of Figure 5 was simplified into 3 zones.

- Northern Zone – rainfall greater than 3600mm per year and up to 9000mm
- Southern Zone – rainfall >1600mm per year and < 3600mm
- Inland – rainfall less than 1600mm

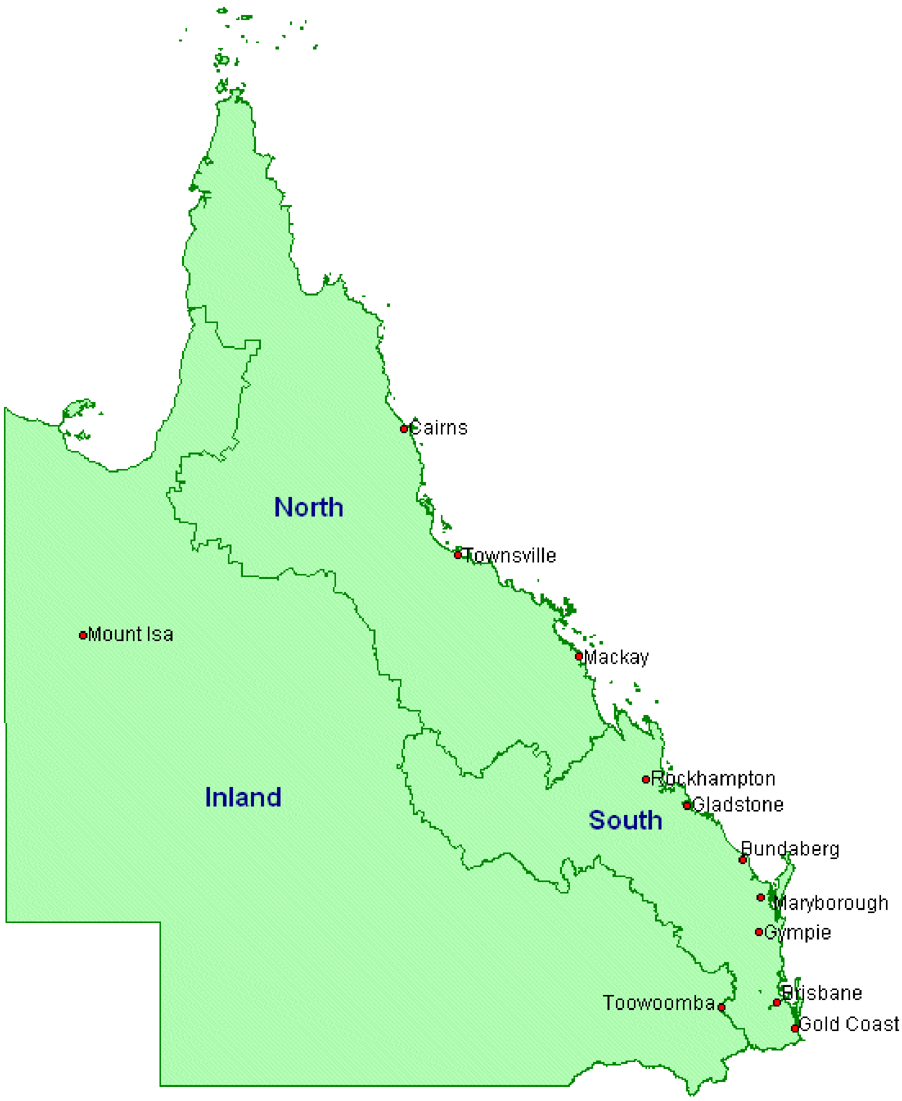


Figure 9. Map of Queensland showing the areas designated for salt accumulation calculations

For each climate zone two salinity zones were used, defined as:

- High salinity - average daily salinity was greater than 10 $mg/m^2.day$
- Low Salinity - average daily salinity was less than 10 $mg/m^2.day$

For each of these six geographic classification, A was derived as a function of ψ and ϕ with ψ varying 0 to 9 and ϕ from 0 to 5. A was derived for each of the locations given in Table 5.

Table 5. Representative locations in the different geographic classifications

Region	Salinity	Location 1	Location 2
Northern	High	Cooktown	
	Low	White Rock	West Cairns
Southern	High	Pinkenba	
	Low	Brisbane	Nudgee
Inland	Low	BoxHill	Box Creek, Morven

However, in order to run the salt deposition program, the variation of A on ψ and ϕ was parameterised. The derivations of the accumulated salt factor A from ψ and ϕ are listed in Table 6 for the different regions in Queensland. The values for the parameters L, F, C, E and R are given for the different seasons and Queensland locations in Table 7. These parameters were derived from the data in Location 1 for each zone and verified for those listed as Location 2.

Table 6. Accumulated salt factor formulae for different Queensland regions

Φ	Location	Accumulated salt factor (A) - %
= 0	ALL	$L*(5*F-\Psi)+E*(\exp-(C*\Psi))$
> 0	North	$L*(1+\Phi*R)(5*F-\Psi)+E*(1+\Phi*R)*(\exp-(C*\Psi))$
	South Inland	$L*(1+\Phi^{\sigma}*R)(5*F-\Psi)+E*(1+\Phi^{\sigma}*R)*(\exp(G*\Phi^{\sigma})-(C*\Psi))$

The values for the parameters L, F, C, E and R are given for the different seasons and Queensland locations in Table 7.

Table 7. Parameters for calculating salt accumulation factor

Location	Salinity	Ψ	Parameters	Summer	Autumn	Winter	Spring
North	High	<1	L	0.035	0.23	0.35	0.29
			F	1.2	1.2	1.2	1.2
			E	0.32	3.1	6.65	3.17
			C	9	9	9	9
			R	5	7	2	3.1
		≥ 1	L	0.035	0.23	0.35	0.29
			F	1.2	1.2	1.2	1.2
			E	0.32	3.1	6.65	3.17
			C	9	9	9	9
			R	0.26	0.55	0.8	0.5

Table 8 (cont). Parameters for calculating salt accumulation factor

Location	Salinity	Ψ	Parameters	Summer	Autumn	Winter	Spring
North							
	Low	<1	L	0.027	0.28	0.8	0.21
			F	1.2	1.2	1.2	1.2
			E	1.1	5.3	27	8
			C	9	9	9	9
			R	20	11	3	9
		≥ 1	L	0.027	0.28	0.8	0.21
			F	1.2	1.2	1.2	1.2
			E	1.1	5.3	27	8
			C	9	9	9	9
			R	1.7	1.05	1.9	1.6
South	High	<1	L	0.038	0.174	0.4	0.19
			F	1.2	1.2	1.2	1.2
			E	1.3	5.9	15.3	8
			C	9	9	9	9
			R	15	10	5	9
			G	2.2	0.9	0.28	0.8
			σ	0.05	0.1	0.2	0.07
		≥ 1	L	0.038	0.174	0.4	0.19
			F	1.2	1.2	1.2	1.2
			E	1.3	5.9	15.3	8
			C	9	9	9	9
			R	1	1	1.5	1.6
			G	0.3	0.3	0.4	0.4
			σ	2.2	2	1.5	1.7
	Low	<1	L	0.046	0.174	0.426	0.125
			F	1.2	1.2	1.2	1.2
			E	1.65	6.5	15.6	5.8
			C	9	9	9	9
			R	20	10	4	10
			G	1.7	0.7	0.3	1
			σ	0.05	0.12	0.25	0.08
		≥ 1	L	0.046	0.174	0.426	0.125
			F	1.2	1.2	1.2	1.2
			E	1.65	6.5	15.6	5.8
			C	9	9	9	9
			R	0.7	1.1	1.4	1.4
			G	1	0.78	1	1
			σ	1.57	1.65	1.35	1.51

Table 9 (cont). Parameters for calculating salt accumulation factor

Location	Salinity	Ψ	Parameters	Summer	Autumn	Winter	Spring
Inland	Low	<1	L	0.07	0.27	0.24	0.13
			F	1.2	1.2	1.2	1.2
			E	3.35	12.2	11.3	7.1
			C	9	9	9	9
			R	12	9	11	12
			G	1.8	0.5	0.6	0.9
			σ	0.1	0.1	0.1	0.1
		≥ 1	L	0.07	0.27	0.24	0.13
			F	1.2	1.2	1.2	1.2
			E	3.35	12.2	11.3	7.1
			C	9	9	9	9
			R	1	1.7	3	2
			G	1	0.5	0.6	1
			σ	1.51	1.85	1.5	1.49

Thus in estimating the accumulated salt at any location and for any bridge position, the values of ψ and ϕ are calculated (these are defined for the different bridge components and are independent of geographic location) and depend on the equations,

$$\phi = \alpha\,(\phi_{3c} + \phi_{3i}) \qquad \text{Eqn(11)}$$

$$\psi = \alpha\eta \qquad \text{Eqn(12)}$$

All the values for the different parameters for the nine bridge components are listed in Table 8. The bridge component defines the parameters and for a given location, A is then calculated.

Table 10 Parameter values for the different bridge components

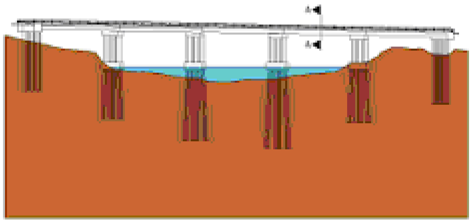
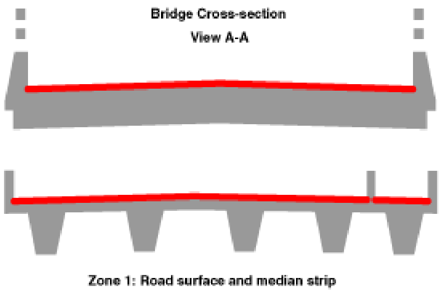
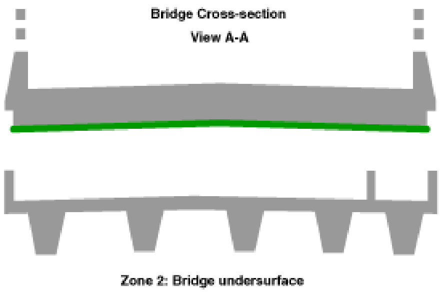
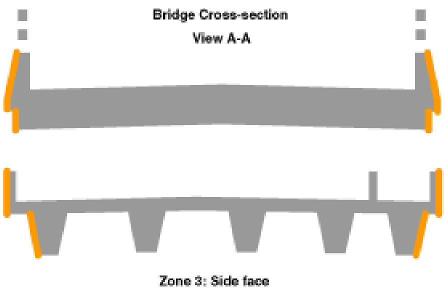
Bridge section	α	Φ_C	Φ_i	η	Φ	Ψ
Bridge overview 						
1. Road surface and median strip Painted concrete 	1.5	0	0.04	1	0.06	1.5
2. Bridge under-surface Bare concrete - rough finish 	1.5	1.2	0.31	0	2.265	0
3. Side face Bare concrete - smooth finish 	1.5	0.61	0.09	0.8	1.05	1.2

Table 11 (cont) Parameter values for the different bridge components

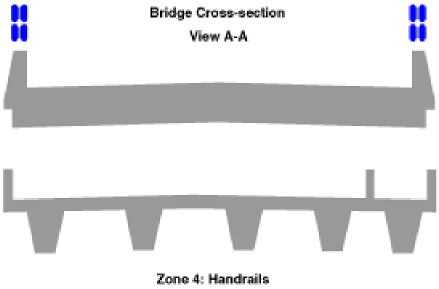
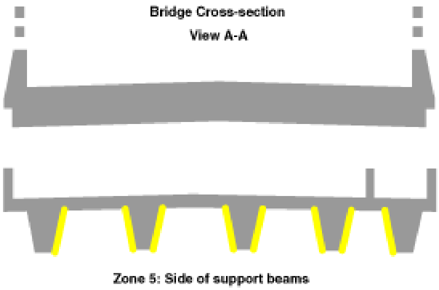
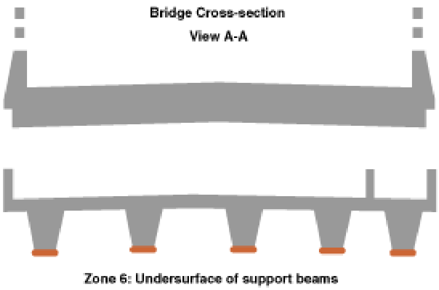
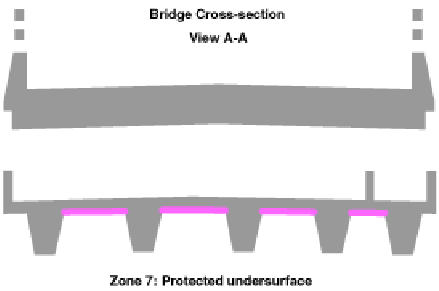
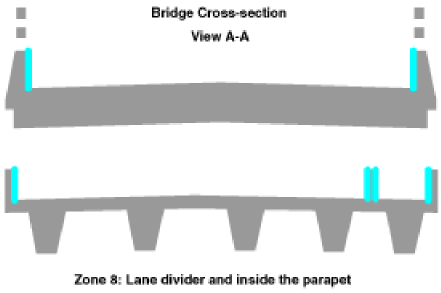
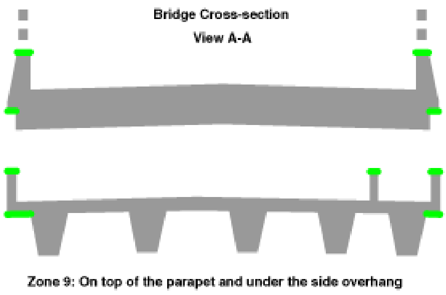
<table>
<tr><th>Bridge section</th><th>α</th><th>Φ_C</th><th>Φ_i</th><th>η</th><th>Φ</th><th>Ψ</th></tr>
<tr><td>4. Handrails
Bare metal - uncorroded

</td><td>1.5</td><td>0.43</td><td>0.17</td><td>0.3</td><td>0.9</td><td>0.45</td></tr>
<tr><td>5. Side of support beams
Bare concrete - rough finish

</td><td>1.5</td><td>1.2</td><td>0.31</td><td>0.05</td><td>2.265</td><td>0.075</td></tr>
<tr><td>6. Under-surface of support beams
Bare concrete - rough finish

</td><td>1.5</td><td>1.2</td><td>0.31</td><td>0</td><td>2.265</td><td>0</td></tr>
<tr><td>7. Protected under-surface
Bare concrete - rough finish

</td><td>1.5</td><td>1.2</td><td>0.31</td><td>0</td><td>2.265</td><td>0</td></tr>
</table>

Table 12 (cont) Parameter values for the different bridge components

Bridge section	α	Φ_C	Φ_i	η	Φ	Ψ
8. Lane divider and inside the parapet Bare concrete - smooth finish  	1.5	0.61	0.092	0.8	1.053	1.2
9. On top of the parapet and under the side overhang Bare concrete - smooth finish  	1.5	0.61	0.092	1	1.053	1.5

4 IMPLICATIONS AND REPRESENTATION OF SALT ACCUMULATION

The amount of salt that can accumulate on a structure has a pronounced effect on the degradation of that structure. The accumulated salt can in fact be more important that the deposition rate depending on the material of construction. In the bridge program both the estimated daily deposition value and the annual accumulated value are given.

In the Final screen of the bridge program the following data are given:

1. Longitude and latitude (only available within Queensland)
2. Salinity in mg/m^2.day and in mg/m^2.year – This is a deposition rate on to a salt candle in the general location of the bridge. It does not indicate that that level of salt will be on either the salt candle or the bridge . To calculate the deposition rate on a particular member the general deposition rate needs to be multiplied by the “salt factor” for the particular element. The accumulation on a particular element is then the product of the general salinity, the salt factor and the accumulation factors for particular elements. The salinity per year is the amount of salt that would accumulate if cleaning was ineffective (for a salt factor of 1) and thus is the upper level of salt expected to accumulate.

3. Salt factor – This is the relative value of salt deposition on a particular member relative to the general deposition rate.
4. Salt Deposition on the Bridge Member- Is the estimated deposition rate of the actual bridge member. It is the salinity x salt factor
5. Salt Accumulation on The Bridge Member – Is the estimated accumulation on the bridge member over a year and is the salinity x salt factor x accumulation factor. This takes into account the effect of rainfall in cleaning off the salt.
6. Risk From Salt accumulation
    - Very Low – Salt Accumulation <300 mg/m^2.day
    - Low – salt accumulation from 500 to 1000 mg/m^2.day
    - Moderate – Salt accumulation from 1000 to 3000 mg/m^2.day
    - High – Salt accumulation from 3000 to 5000 mg/m^2.day
    - Very High – Salt accumulation >5000 mg/m^2,day

The salt accumulation and thus salt concentration on the surface will drive salt diffusion through the surface and thus be a major factor controlling the durability of the structure.

5 CONCLUSIONS

The bridge program developed in the previous phase of this project which predicted salt deposition on Queensland bridges has been modified to include the effects of natural cleaning from rainfall.

6 REFERENCES

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