Estimating the Contribution of Road Runoff to Receiving Environments Close to State Highways

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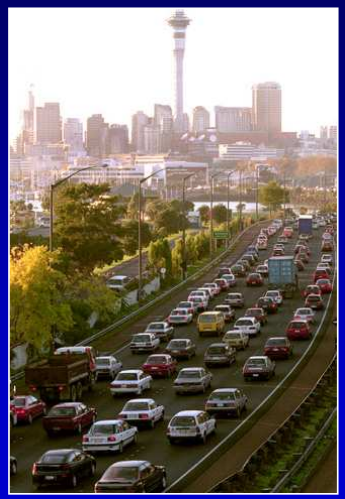
NZ TRANSPORT AGENCY
WAKA KOTAHI

NIWA
Taihoro Nukurangi

Background:

- Land Transport Act (2003)
- requires:
- …improved social and environmental responsibility in land transport funding, planning and management
- significant challenges for NZ Transport Agency ⇒
- **costing the effects of road runoff on aquatic ecosystems**



NZ Transport Agency approach:

- NZ Transport Agency ⇒ **4 Stage** assessment of adverse environmental effects

1) **identification of sensitive receiving environments (SRE's)**
2) **assessment of contribution of road runoff to sediment contamination**
3) **preparation of a stormwater treatment standard**
4) **evaluation of overseas predicative assessment tools for usefulness in New Zealand** (UK & US Highway Agency's)

NIWA study concerned primarily with (2)


The aims of the research project:

1) develop sampling sediment sampling strategy

2) determine whether there is a correlation between sediment contaminants & catchment VKT (proxy for 'load')

- important for the assessment of SRE's

(1) Identification of SRE's

- Land Transport NZ Research Report #315
  - Identifying Sensitive Receiving Environments at Risk from Road Runoff (Gardiner & Armstrong, MWH)
- SRE rating comprised of:
- *sensitivity rating factor (SRf)*
  - (1) **type sensitivity**; (2) **ecological value**; (3) human use value
- *pathway factor (Pf)*
  - types: **direct**; **indirect**; diffuse
- *source strength (S)* ⇒ mass units per day: e.g. mg zinc/day

'overall pollution risk' **(*R*) = (*SRf*) x (*Pf*) x (*S*)**

- difficult to obtain accurate source strength data ∴
  - use catchment VKT as proxy for runoff quality ⇒ **Tier 1 assessment**

The aims of the research project:

1) develop sampling sediment sampling strategy

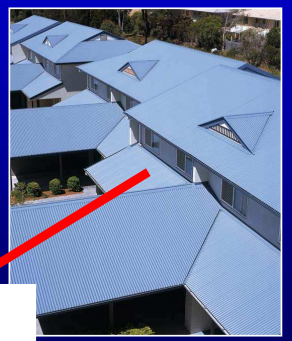
2) determine whether there is a correlation between sediment contaminants & catchment VKT (proxy for 'load')

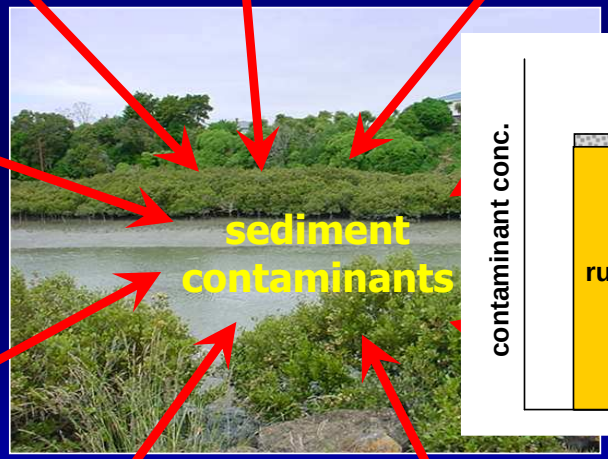
- important for identifying SRE's

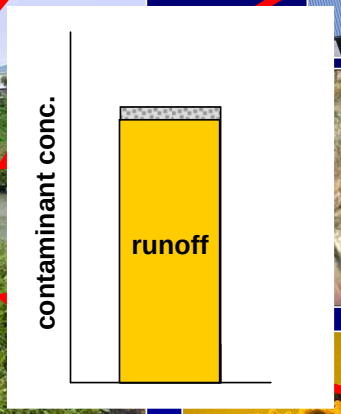
3) estimate the contribution of road runoff to sediment contaminant concentrations in receiving environments

Contribution of road runoff contaminants

- what do we mean?





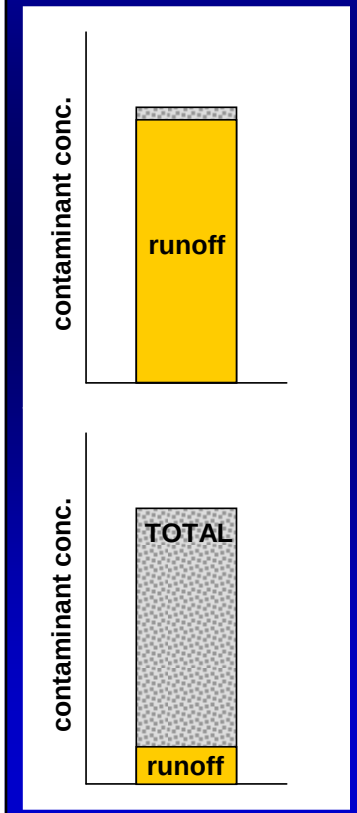


- benefits?

Contribution of road runoff: *cost/benefit*

- prioritisation of stormwater treatment & level required
- apportioning cost/responsibility for any 'impacts'

road runoff contribution	potential for treatment to improve sediment 'quality'



HIGH ⇨

treating major source of sediment contamination

LOW ⇨

treating only minor source – most contaminants from other sources/historic

Methods:

- determine diagnostic ratios of contaminants in a representative road runoff sample
- contaminants of interest:
  - heavy metals:
    - zinc (Zn)
    - copper (Cu)
  - organic contaminants:
    - polycyclic aromatic hydrocarbons (PAHs) – '16 priority US EPA'
    - total petroleum hydrocarbons (TPH)
- use ratios to estimate the proportion of sediment contaminants attributable to road runoff in potential SRE's (Auckland)
- …requires a suitable road runoff 'standard' material
  - $\Rightarrow$ although road runoff is made up of multiple sources…

Road runoff: a mixed contaminant source

- …not just transport-related sources

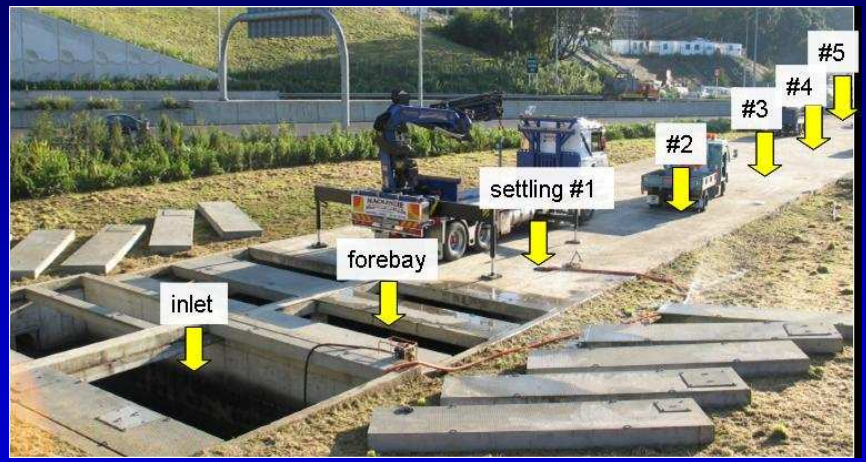
road related

non-transport sources

need a 'reference' source material that optimises road-related inputs…

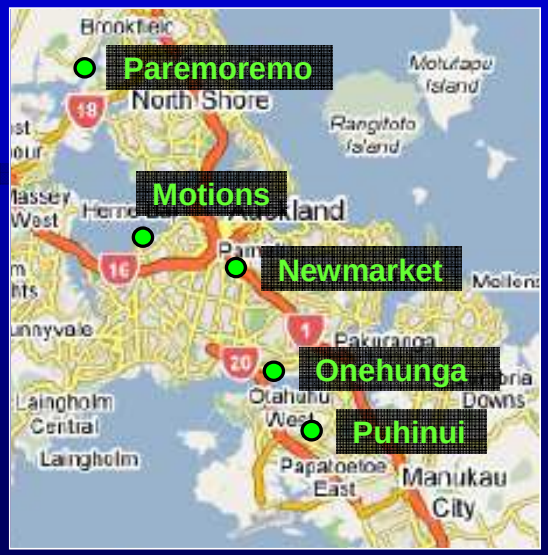
Grafton Gully stormwater treatment tank

- largest SWTD device in NZ (100x10x2.5 m)
- commissioned ca. 2003
- comprised of inlet, forebay and 85m settling tank
- in its absence:
  - coarse particulates would deposit in streams
  - finer particulates would settle in estuaries
- catchment dominated by high traffic volume roads



Auckland catchments

Motions
VKT = 478,806



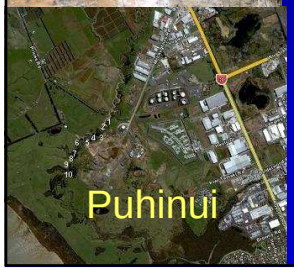
Paremoremo
VKT = 427,273

Newmarket
VKT = 444,885

Onehunga
VKT = 691,419

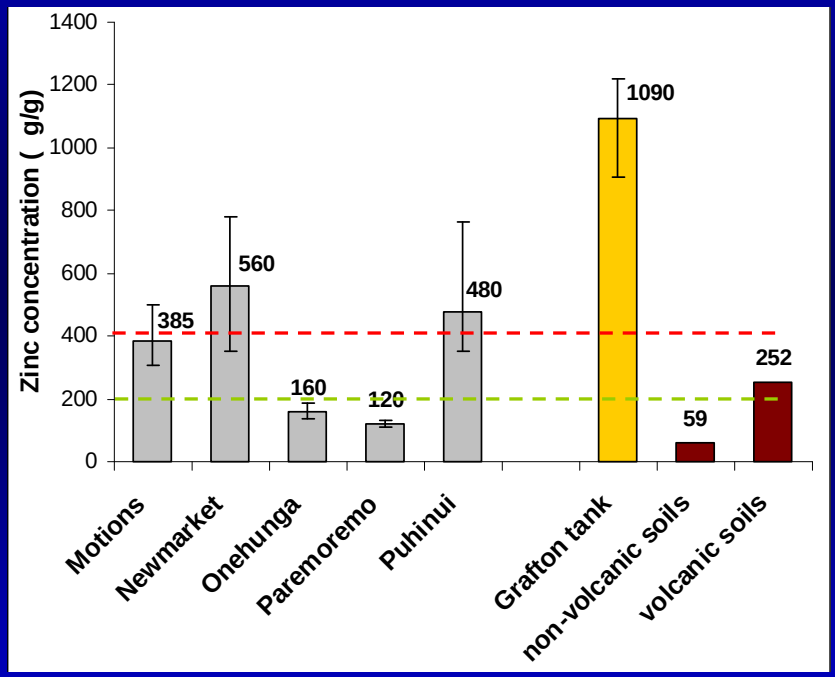
Puhinui
VKT = 481,231


Concentrations
heavy metals
PAHs

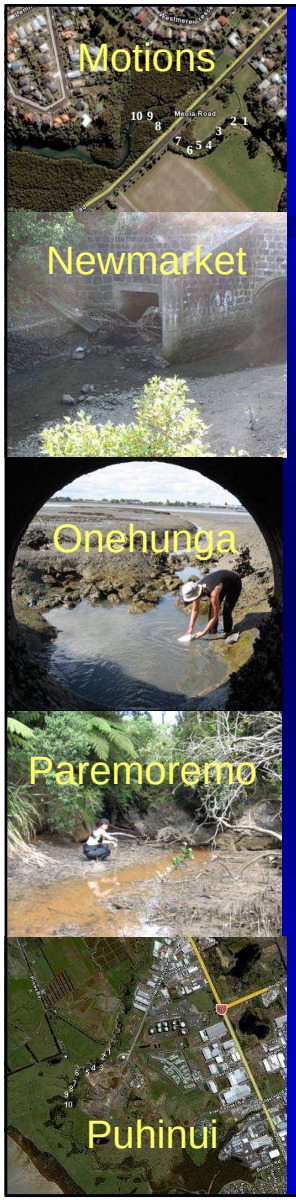


Heavy metals in sediments: zinc

- 120 – 560 mg/kg
- Grafton sed. = 1090 mg/kg
- ANZECC LOW = 200 mg/kg ANZECC HIGH = 410 mg/kg

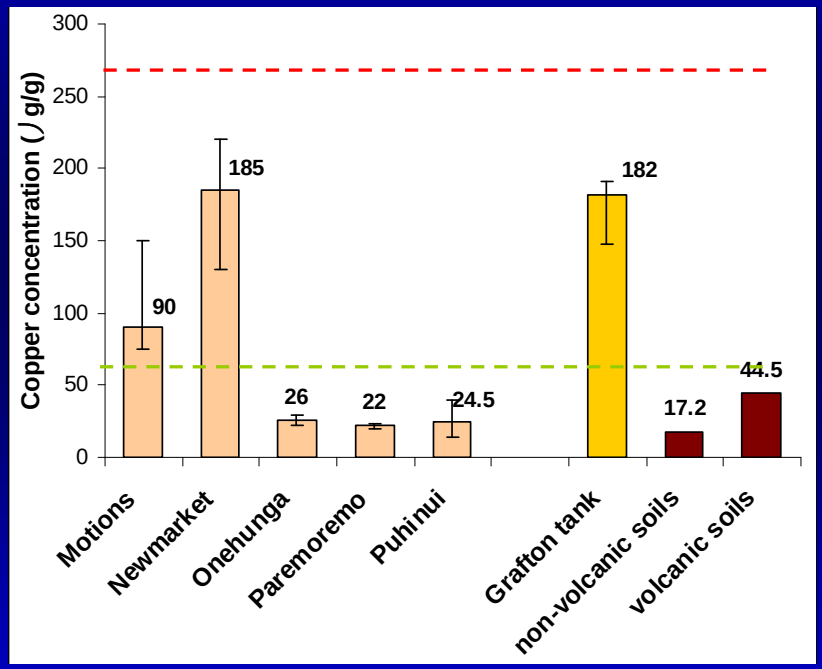


- 3 sites + Grafton exceed ANZECC ISQG-High value for Zn
- background [Zn] significant @ Onehunga & Paremoremo



Heavy metals in sediments: copper

- 22 – 185 mg/kg
- Grafton sed. = 182 mg/kg
- ANZECC LOW = 65 mg/kg ANZECC HIGH = 270 mg/kg



- 3 sites + Grafton exceed ANZECC ISQG-High value for Zn
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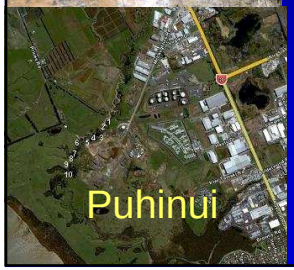
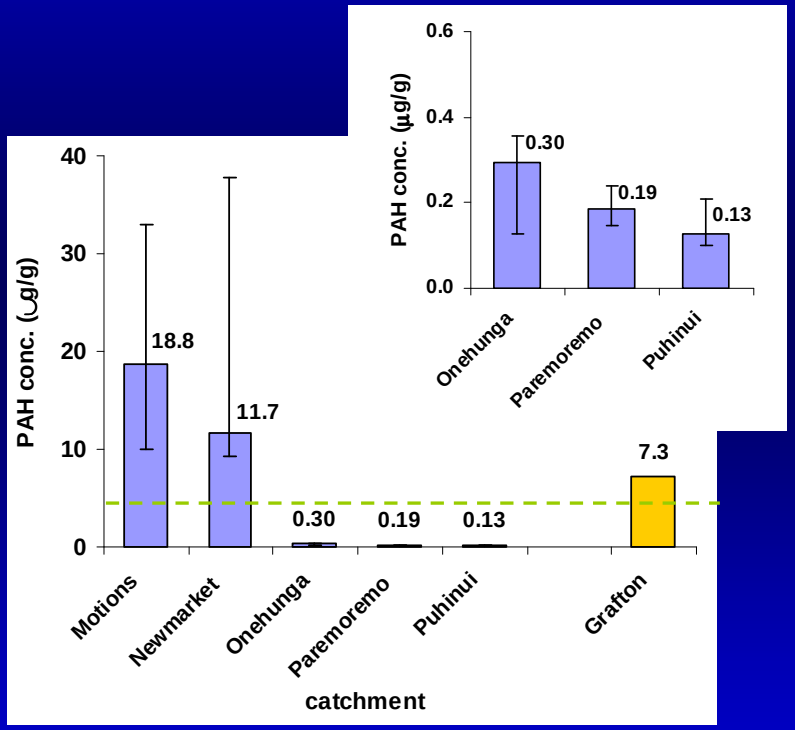


PAHs in sediments

- 5 catchments classified into 2 groups:
  - 'HIGH' (>10 mg/kg): Motions & Newmarket
  - 'LOW' (<1 mg/kg): Onehunga, Paremoremo & Puhinui



- ANZECC 'LOW' trigger value for PAHs = 4 mg/kg


Reconciling source
concentration
ratios

Concentration: source vs. sediment

dilution

dilution

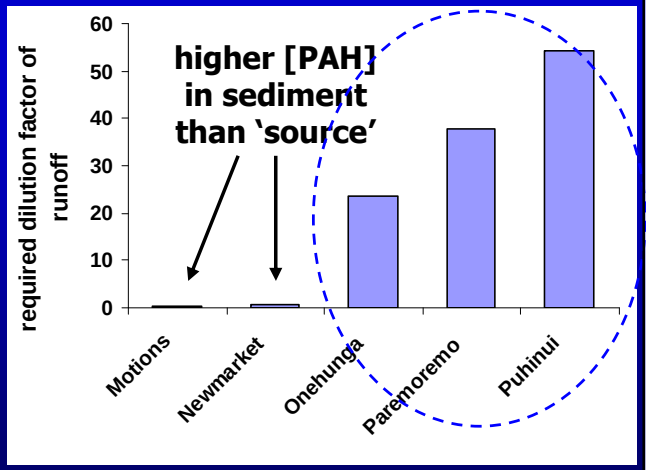
- runoff particulate source material diluted during transportation & deposition in receiving environment sediment
- Grafton SWTD ('source') = **7 mg/kg** PAH

transportation/dilution by non-anthropogenic material (soil/plant)

- sediment ('sink') expect <<**7 mg/kg** PAH
- ⇒ estimate dilution factors ([sink]/[source])
  - first 'look' to reconcile source/sink contaminants
- dilution depends on:
  - 'pathway' (ie. direct/indirect/diffuse)
  - representative 'source' strength (Grafton)

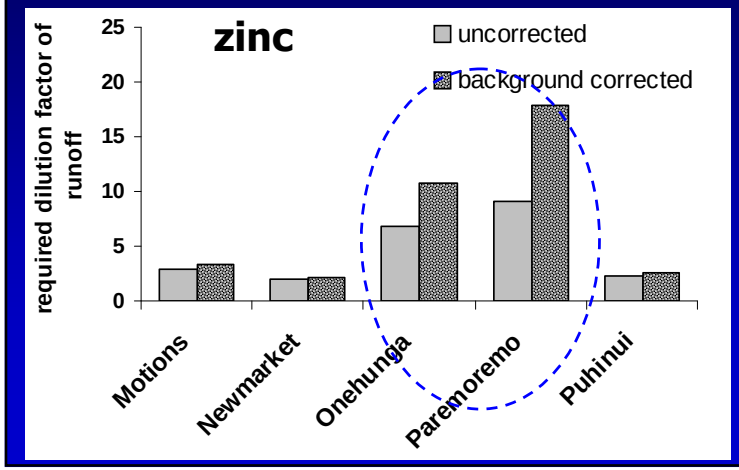
Dilution of contaminants

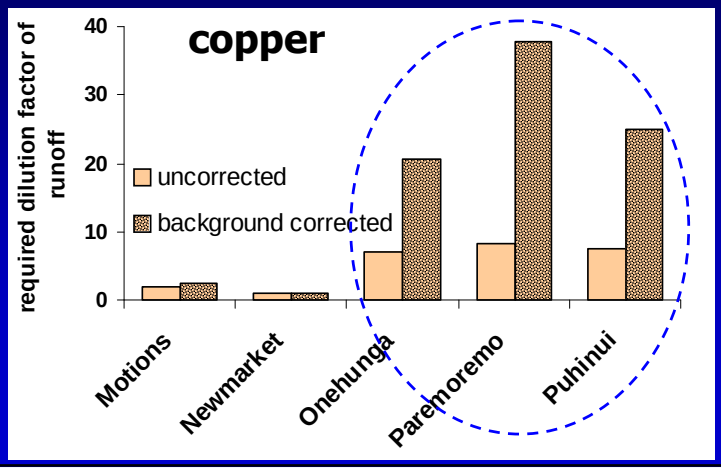
- PAHs
- Motions & Newmarket sediment would require concentration of Grafton runoff!
- dilution factors of 20-50 for Onehunga, Paremoremo & Puhinui



- Heavy metals
- problem: background concentrations significant ⇒ uncertainty
- similar trend to PAHs; Puhinui very high Zn relative to Cu & PAH

low dilution factor ⇒ difficult to reconcile runoff as main source



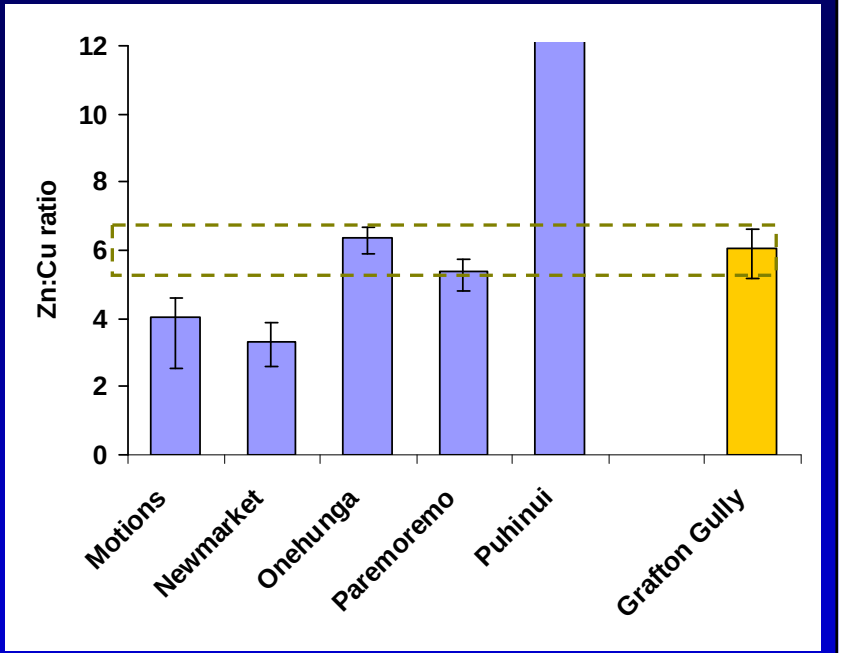


Zinc : copper ratio (qualitative)

- main concept:
- *if runoff particulates a major source, then Zn:Cu ratio in environmental sediments (sink) ≈ runoff particulates (source)*
- if not ... ⇒ evidence of 'other' major source

- note: based on Grafton being 'representative' of road runoff particulates from traffic-dominated catchment (since focus is on transport-related inputs)

- main points:
- Onehunga & Paremoremo consistent with road runoff being main source of Zn/Cu
- Puhinui has other significant Zn source (Zn:Cu = 20)
- Motions/Newmarket sediments have relative enrichment of Cu

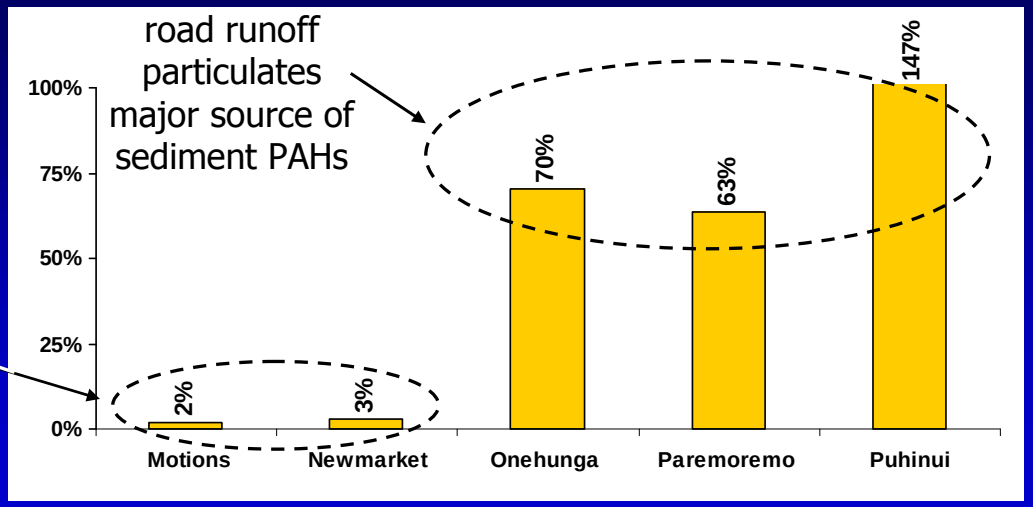


Estimating PAH contribution (semi-quantitative)

- measure compounds called hopanes
- refractory compounds in crude oil residue (bitumen)
- assume all sediment hopanes due to road runoff
- determine representative hopane:PAH ratio (Grafton)
- based on sediment hopane ⇒ calc. PAH from RDS

$$\text{CONTRIBUTION} = [\text{PAH}]_{\text{RDS calc.}} / [\text{PAH}]_{\text{sed. total}} \times 100$$

what is source of PAHs in these catchments?



Historic vs. present road runoff: **Coal Tar**

- Prior to 1960-70's many road used coal tar in construction

'Present'

bitumen

petrogenic source

20-30 µg/g PAHs

'Historic'

coal tar

pyrogenic source

>100,000 µg/g

- implications for road runoff PAH load:

Scenario: road runoff particulates contain **0.5%** binder

500 ppm PAH

historic inputs

(coal tar)

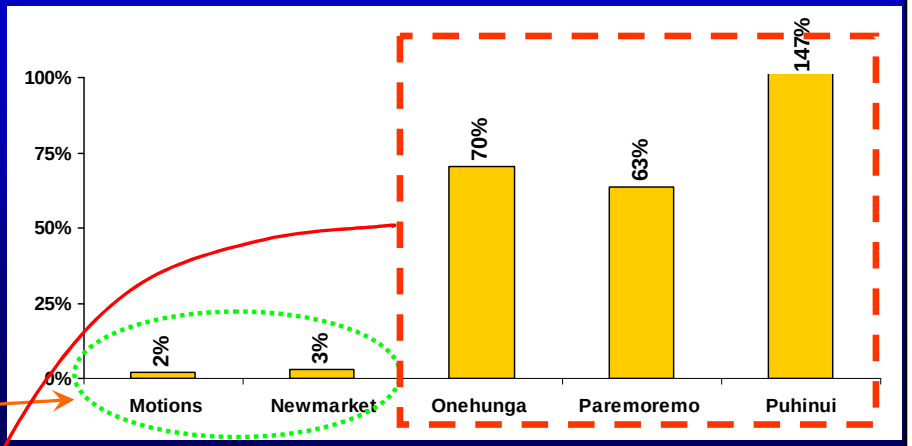
0.15 ppm PAH

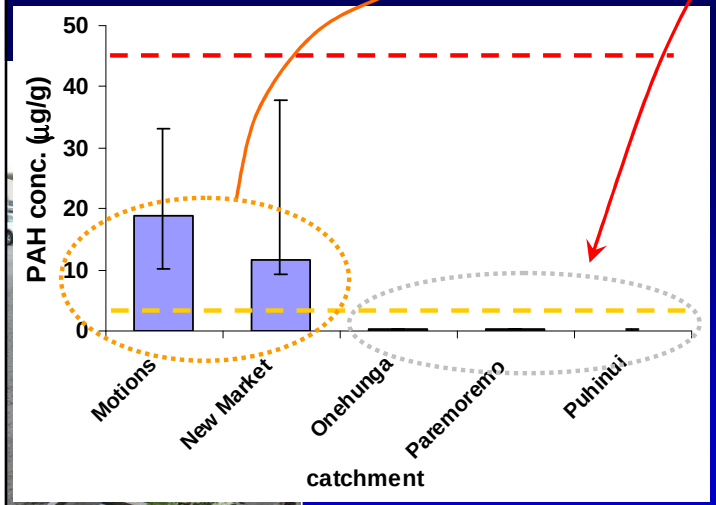
present inputs

(bitumen)

Estimating PAH contribution II

- sediments of concern:
  - RDS contribution LOW
  - low potential to improve via treatment?
- RDS contribution HIGH
  - sediments of no concern
  - low cost/benefit ratio





Summary Table

Catchment	Estimated contribution of RDS to sed. PAHs (%)	Sediment [PAH] relative to ANZECC 'LOW'	PAH sediment levels of concern
Motions	2-3	4.7	YES
Newmarket	3-5	2.9	YES
Onehunga	70-100	0.075	NO
Paremoremo	63-100	0.048	NO
Puhinui	100	0.033	NO

Summary

looking at original aims…

- **1)** develop sampling sediment sampling strategy
  - current strategy didn't provide background concentrations
  - New sampling to use short cores (top =impacts; bottom = bkgd)
- **2)** is there correlation between sediment contaminants & catchment VKT (proxy for 'load')
  - Can not be easily achieved unless catchments are either selected with similar (or are able to be normalised for differences in) ⇒
  - pathway type, source strength, dilution from non-anthropogenic sediment

Summary (cont.)

- **3)** estimate the contribution of road runoff to sediment contaminant concentrations in receiving environments
  - Yes –estimated of inputs – but only using PAH (at present)
  - Useful to be able to perform similar 'semi-quantitative' contribution estimates for heavy metals (currently only qualitative assessment)
  - Based on PAHs…
  - catchments with high sediment [PAH] ⇒ low road runoff contribution
    - Other source of PAHs is coal tar (via historic road runoff inputs)
  - Catchment where runoff major source ⇒ sediment [contaminant] low