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Terrestrial gamma radiation baseline mapping using ultra low density sampling methods

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ABSTRACT

Baseline terrestrial gamma radiation maps are indispensable for providing basic reference information that may be used in assessing the impact of a radiation related incident, performing epidemiological studies, remediating land contaminated with radioactive materials, assessment of land use applications and resource prospectivity. For a large land mass, such as Queensland, Australia (over 1.7 million km^2), it is prohibitively expensive and practically difficult to undertake detailed *in-situ* radiometric surveys of this scale. It is proposed that an existing, ultra-low density sampling program already undertaken for the purpose of a nationwide soil survey project be utilised to develop a baseline terrestrial gamma radiation map. Geoelement data derived from the National Geochemistry Survey of Australia (NGSA) was used to construct a baseline terrestrial gamma air kerma rate map, delineated by major drainage catchments, for Queensland. Three drainage catchments (sampled at the catchment outlet) spanning low, medium and high radioelement concentrations were selected for validation of the methodology using radiometric techniques including *in-situ* measurements and soil sampling for high resolution gamma spectrometry, and comparative non-radiometric analysis. A Queensland mean terrestrial air kerma rate, as calculated from the NGSA outlet sediment uranium, thorium and potassium concentrations, of 49 ± 69 nGy h^{-1} ($n = 311$, 3σ 99% confidence level) is proposed as being suitable for use as a generic terrestrial air kerma rate background range. Validation results indicate that catchment outlet measurements are representative of the range of results obtained across the catchment and that the NGSA geoelement data is suitable for calculation and mapping of terrestrial air kerma rate.

1. Background

1.1. Baseline mapping

Baseline radiation surveys are generally conducted on an as needs basis, most commonly where a new radiation practice (e.g. uranium/rare earth exploration & mining operation or waste disposal facility) is being developed or used to extract, process, handle, store or dispose of radioactive materials. Additionally, a baseline, or background radiation survey may also be required when land contaminated by radioactive material undergoes a land use change, or has been impacted upon by some past, uncontrolled radiation practice or malicious act, and remediation of the site is required (IAEA, 2011; RH, 2002). Baseline radiological data may also be utilised in estimating dose to non-human species and in geomedicine applications (Sanderson et al., 2012; Jones et al., 2009). It is generally accepted that it is necessary to establish areas of similar geographic, geological and environmental conditions in reasonable proximity to a site of interest that can be used for a baseline or background assessment. The assessment data is ultimately used to provide target remediation, decontamination or post operations levels. In addition to remediation of contaminated sites and facilities, baseline data can be used as a measure in nuclear emergency preparedness, monitoring and remediation (Aboelkhair and Rabei, 2012; IAEA, 2010). Typical baseline data includes terrestrial gamma radiation, soil and sediment specific radioactivity, surface and groundwater radionuclide characterisation, biota and air (e.g. dust, radon) radioactivity concentration. These parameters, at a basic level, should include naturally occurring radionuclides, and additionally include anthropogenic radionuclides where their presence is known or expected.

While baseline studies of large land areas have been conducted elsewhere (Alharbi et al., 2011; Appleton et al., 2008; Beamish and White, 2011; Bellotti et al., 2008; Green et al., 1992; Minty, 2011;

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Tracy et al., 1996; Rybach et al., 2012; Wilford et al., 2011; Xiong et al., 2012), there are no publically documented, state-wide radiological baseline data sets available for Queensland, Australia other than those provided in previous aerial radiometric surveys. For a large geographical area such as Queensland, over 1.7 million square kilometres, the cost of representative sediment/soil sampling and radioanalysis of all the identified parameters is significant, and it is reasonable to look to surrogate methods to deliver an alternative means of providing the required data, subject to the method being adequately validated.

This work documents a methodology for estimating, and mapping (including validation), of terrestrial air kerma rate over large land masses using ultra low density sediment sampling geochemical data. The advantages of the proposed method include the ability to rapidly, and at low cost, sample a small number of sediment samples at the outlet of a drainage catchment, these samples being considered as representative of the whole catchment. From the geochemical analytical data obtained, radiometric characteristics can be derived and used for mapping purposes. It is proposed that the radiometric data may be calculated from parameters that can be determined by common non-radiometric techniques (e.g. ICP–MS), providing easy access to radiometric information in locations where availability of specialist radioanalytical laboratories may be restricted, or access to aerial radiometric data is unavailable or difficult to acquire.

1.2. Ultra low density sediment sampling

It is difficult and expensive to conduct comprehensive sediment or soil sampling programs over large land masses. Drainage catchment sediment sampling is recognised as being a suitable method to overcome these challenges. Overbank sediments are deposited as a result of the flooding of streams and rivers, and are typically found on the flood plains of water courses as horizontal strata of young sediments overlaying older deposits (Fig. 1). It has been observed that overbank sediments are more representative of sediment from a drainage catchment than that derived from an active stream bed which tend to represent localised mineralisation and possibly pollution sources (Bolviken et al., 2004; Caritat et al., 2007; Eden and Bjorklund, 1994; Fletcher, 1997; Ottesen et al., 1989; Ridgeway et al., 1995; Volden et al., 1997; Xie and Cheng, 1997).

1.3. National Geochemistry Survey of Australia

The National Geochemistry Survey of Australia (NGSA) sampled transported regolith, as overbank sediment, from over 1000 major river catchments across Australia to generate a nationwide geochemical database (Caritat and Cooper, 2011b). In Queensland, a total of 311 catchments were sampled (Fig. 2), providing an average sampling density of approximately one location per 5500 km^2. Catchments less than 1000 km^2, and islands, were not included in the study. All samples were collected at the drainage catchment outlet, or where this was ill-defined, at the lowest point within the catchment. Based on the theoretical ideals of overbank sediment sampling, it was considered that these catchment samples would be representative of the total catchment geochemistry (Caritat et al., 2007) (Fig. 3).

NGSA samples from the catchment outlets were collected at two depths, a surface sample to 100 mm, identified as Top Outlet Sediment (TOS), and a second sample at a depth of between 600 mm and 900 mm, the Bottom Outlet Sediment (BOS).

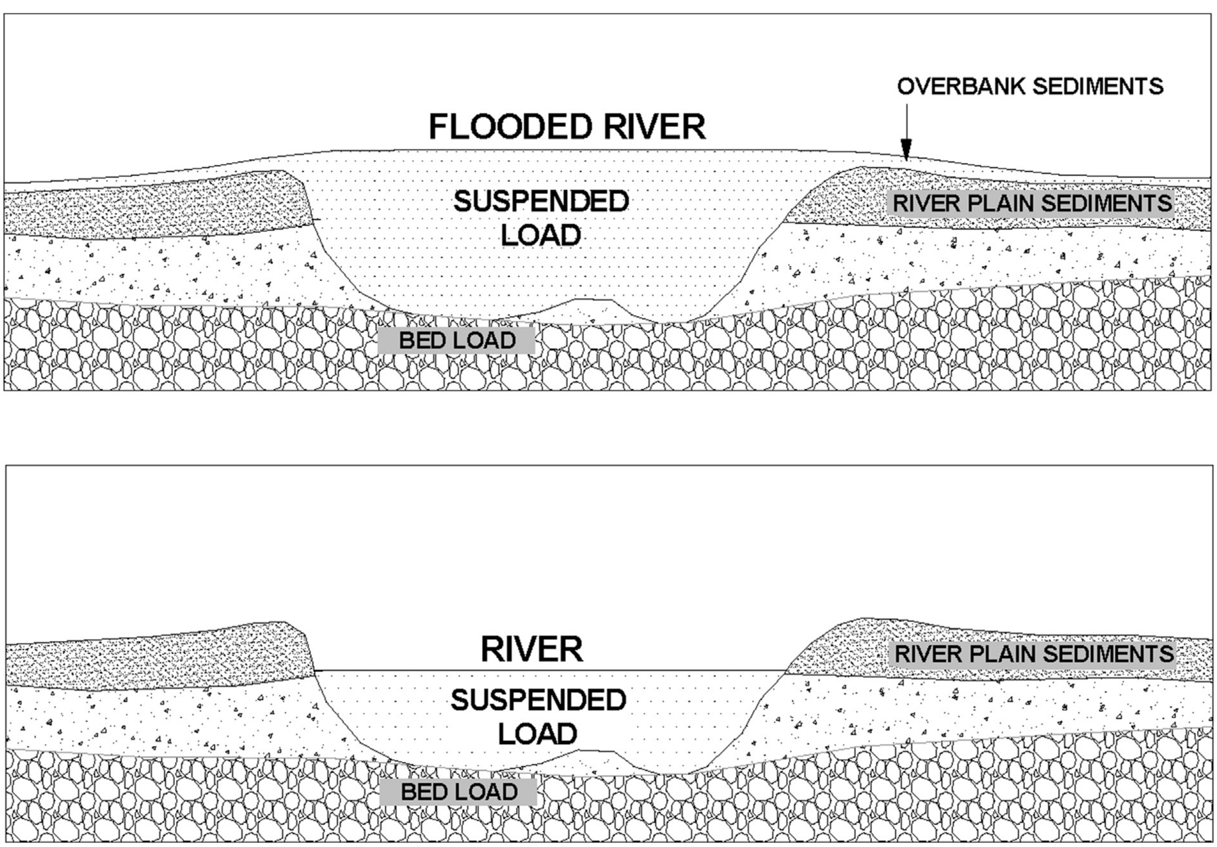

Fig. 1. Overbank sediment schematic showing sediment deposition mechanism.