HARBOUR-SIDE LAND PARCEL LAND-USE CHANGES
SIGNIFICANCE IN RE-DEVELOPMENT PLANNING PERMIT APPRAISAL IN MELBOURNE, AUSTRALIA

Mr Damien Luxford, Centre for GIS, School of Geography and Environmental Science, Monash University, Melbourne
Dr Shobhit Chandra, Centre for GIS, School of Geography and Environmental Science, Monash University, Melbourne

Correspondance to Shobhit Chandra: Shobhit.Chandra@arts.monash.edu.au

Results are presented of spatial query at the land parcel level of a (digital) spatial database, referring to the twentieth century Harbour-side zone of the Port of Melbourne. They refer mainly to land-use histories of individual land parcels. Such histories can be now deployed routinely in decision support during assessment of heritage potential in aid of re-development/excavation permit appraisal.

Such query has long been possible in a general way: the innovation brought forward in this presentation refers to the new level of detail that is achieved by adopting digital spatial database query. The prerequisite for such query is the kind of digital spatial database that we have built from imposing spatial compatibility on archival maps and air photos.

It is argued that much interest will attach to implementing the spatial database building process exemplified in this paper for decision-making in planning permit appraisal. For instance, contaminated ground might be better identified. Modern data handling tools make this feasible in a routine way if the necessary data and information flow paths and data sharing can be arranged.

INTRODUCTION

The built environment is, suspended in a constant state of flux. Its built form and character change in response to pressures from without and within, advances in mechanisation and technology, and generational shifts in the philosophical, social and economic fabric, in a way summarised by Parkes et al. (1980, p. 415) as evidence for “cycles” in the built environment. Inwards from the periphery, a city cannibalises and replenishes itself. New use is found for old land; nature’s topographic framework is garnished with a succession of veneers. Even the topographic framework itself is reshaped. National urban building cycles are seen to have local components (eg see Gottlieb 1976).

Although comparatively young by world standards, Melbourne has experienced its share of these processes (Davison 1978), and many parts have been transfigured almost past recognition. The docks precinct is one example (see Figures 1, 2 and 3). From beginnings at Queens Wharf in 1839 (Lewis1995, p. 23 ) there has been an almost continual process of Harbour-side landscape modification and renewal (Lewis 1991) with dredging and landfill, industrial development and, most recently, the beginning of high-density urbanization on former swamp and industrial land. The region has been an important hub of manufacturing, transport and commerce since colonial times, due in part to the importance of the Yarra River as an avenue of transport, and also partially due to its positioning between the townships of Melbourne and Williamstown, the twin nuclei.
from which the Port Phillip settlement grew. So it was that many of the fledgling city's first impor-
tant depots and manufactories were sited on or close to the banks of the Yarra and lower Maribyrnong rivers.

Much of the change in landform and land-use within a city can be traced through maps. In Australia, these have been around since the time of first settlement, and have survived to offer a time-series archive. It is fortunate that many amongst the 19th and early 20th century mapmakers were meticulous practitioners who took obvious pride in their work. Today's geographer, keen on researching the history of land parcels or regions within the urban fabric, stands to benefit greatly from their legacy, if an understanding of the nature of the archives and the cartographic techniques that were used can be brought to bear. More recently, the maps have been complemented by sets of aerial photographs. For Greater Melbourne these date back to 1931. Photos provide an unique perspective of their own, being as near to raw 'snapshots' of given places at given times, as can be achieved. They are particularly useful where the analysis is focused to single-parcel level. Because they display data in substantially disaggregated format, photos provide detail of a kind often ignored by mapmakers. This reflects matters of priority, and/or the need for generalisation, so that the scale of the map or model can be fit for immediate purposes while at the same time not needing too large a model space or paper sheet.

A picture tells a thousand words and as such, a map or a photograph is a valuable source of information, even when considered in isolation. What is, perhaps, not quite so immediately obvious is the degree to which extra information can be extracted when two or more maps or photos are available for data integration. It is a classic situation where the `whole exceeds the
sum of the parts'. Comparing several maps of the one area at different dates provides information not only regarding the magnitude or totality of change itself, but rates and patterns of change also. Once these quantities have been derived they can be interpolated or extrapolated, allowing hypothesis generation and deduction about events between the times of the 'snapshots'.

Figure 2. Docks, 1942

Figure 3. Docks, 2002
Meaningful analysis and collation of historic maps, photos and other data is rarely straightforward. Historical database building is often a lengthy exercise because source data exists in varying formats, scales and datums, and refers to a range of accuracies and varying degrees of precision. Frequently we find, the older the input data is, the more problems are presented. We may expect an ink plan based on survey information collected in the 1870s to have significant irregularities in scale and orientation, due to limitations of measurement techniques and devices employed at that time, (and despite the best efforts of the mapmakers). By no means immune to this principle, air-photography appears to have undergone something of a steady increase in quality and consistency over the first 30 or so years following its introduction.

CONSTITUENTS OF THE TIME-SERIES SPATIAL DATABASE

(A) AERIAL PHOTOGRAPHY

In the science of photogrammetry much theory is devoted to the modelling and removal of inherent geometric distortions. This modelling is underpinned by mathematical algorithms, which use high accuracy ground control points (GCPs). The algorithms apply best to data in digital format; even so, the sheer complexity of the computation involved hitherto, precluded adjustments on regions of significant spatial coverage, unless the results of modelling with low geometric resolution were all that was called for. The recent ‘quantum leap’ in the power of computers has largely solved this problem. It is now possible to simultaneously orthorectify and mosaic ‘blocks’ containing many dozens and even hundreds of photos. Provided we have access to the necessary metadata, and that all pre-conditions (adequate scan resolution and stability, scope for GCP extraction etc) are favourable, modern image processing software packages can simultaneously orthorectify and georeference imagery spanning dozens of square kilometres to sub-metre precision. Rigorous GCP requisition using GPS is preferred, but the digital spatial data infrastructure overlays that can now be imposed on photos of the Melbourne area are adequate to support GCP assembly during orthorectification.

In the heritage context, it is to be expected that most interest attaches to the earliest air photographs in the Melbourne archive. Unfortunately, the quality of many of these is somewhat poor due in part to seven decades of ‘rough and tumble’ treatment at the hands of the public, the loss of original negatives and the subsequent creation of replacement negatives from soiled prints. Also relevant to note is the fact that institutional expertise in air photography and photogrammetry was still at ‘pioneer stage’ among Australian land surveyors in the early 1930s, the planes flew in the most turbulent part of the atmosphere, and aerial camera design had a long way to go. Thus, the images lacked fiducial marks, and the flight lines were not regular.

The whole central, north and west parts of Melbourne (including the docks) was flown at 9000 feet, using a lens of focal length 7”, whilst the south and east was flown at 11000 feet, with a lens of focal length 5’4”.

Effective processing of imagery spanning large geographic areas has been prohibitively slow and complex by traditional optical-mechanical stereoplotter techniques. This is because of the inconsistency between overlapping images in the early air photo sets (1931 and 1942), and also because of the lack of fiducial marks. Only with the advent of the current suite of image-processing programs did such a task become feasible.
The most rigorous method for the simultaneous digital orthorectification of a block of air photos is 'bundle adjustment'. With 'recent' imagery, (1960s onwards), this process is relatively straightforward, and can be expected to yield good results, providing the imagery is documented with the appropriate metadata: focal length, flying height, the precise image coordinates of calibrated fiducial marks, coordinates of the principal point of symmetry and particulars of radial lens distortion. Such information forms part of the 'Camera Calibration Report' attached to all photogrammetric projects. With older, less stable imagery, a measure of fidelity can be achieved through comparison with a recent, rigorously derived mosaic, and indeed, obvious problems can be addressed through registering the former to the latter. Of course, this technique is only effective
where common features appear on both mosaics. This becomes less likely as the time gap increases between images that need to be directly compared.

Aerial photographs, orthorectified, mosaicked and layered in time-series, form the backbone of a spatial database (Table 1). To this 'core' spatial data set, we added data of diverse origins, reference datums and formats.

**B) MAPS**

Archival maps, georeferenced and corrected for distortion, are another critical ingredient of the spatial database. Maps printed from photogrammetric plot sheets, that were output from the analogue plotters of the pre-digital age, can be corrected with a simple geometric transformation. Maps predating the photo archive present quite a different problem. If of broad geographic coverage, these tend to have been based on a raft of local surveys, each with a separate datum. This “piecemeal” arrangement has its roots in the origin of Victoria’s cadastral system. Most of the state’s first maps were either the plans of settlements or parish plans, created during the Hoddle era (1837–1853) (Scurfield 1995, p. 79). The surveys upon which they were based were conducted using relatively crude equipment, (gunter’s chain, compass and primitive theodolite), and were, by and large, hastily executed in an endeavor to get the land onto the market as quickly as possible (Scurfield 1995, Part B, Chapter 1 and Part C, Chapter 2). As a precaution, many colonial surveyors made a habit of laying off excess in distances when chaining parcel boundaries, thus providing a hiatus or safety margin to insure against disputes arising from dimensional imperfections. Not surprisingly, the plans of abutting parishes did not always fit well with one another. Thus it is to be expected that old maps comprising of more than a single parish or ‘township’ will contain significant inconsistencies, and in their original format, will not respond well to correction via mathematical analysis. The technique of dividing such maps up into several sections, subjecting each section to its own correction, and then attempting to mosaic the corrected portions can, to some extent, address this problem. This is best achieved via a bundle adjustment, where the input images, (in this case sections of an image), are treated as photographs originating from a non-metric camera.

**C) AUXILIARY DATA**

Once all the constituents of the digital spatial database share a common frame of reference, any number of maps and/or photomosaics can be collated within a Geographic Information System, (GIS). A range of GIS packages is available on today’s market. Each offers specific tools for the joint display contrast and query of spatial datasets, and for the automated feature extraction and assessment of land-use change. It is now a matter of formality to add pre-existing vector e.g. roads, cadastre, etc and attribute data to the database. If this data is already geo-referenced to the same projection as the mosaics and maps, the step is straightforward. If a difference in projection exists, one or more datasets can be re-projected to achieve consistency.
METHODOLOGY USED IN THE CONSTRUCTION OF THE PROJECT SPATIAL DATABASE FOR MELBOURNE DOCKS AREA

The following section lists, in sequence, the steps taken toward assembly of an historic, spatially consistent and geo-referenced database of the Melbourne docks area with attention to major land use changes dating from the period 1910–2001:

1. Suitable hard-copy images of the study region were selected from air-photo projects dating from January 1942 and September 2001. The earlier project was obtained from the archives at Land Victoria, while the later project was purchased from United Photo and Graphic Studios. All photos were scanned at 600 dpi. (Given an approximate image scale of 1:10000 this provides a spatial resolution of about 0.4 metre (Spatial resolution = the actual ground coverage area of a single pixel in the image). The scanned files were stored in separate folders, and were initially prepared using Adobe Photoshop LE to enhance contrast.

2. A paper map of the Melbourne Ports area were sourced from a 1910 Melbourne Harbor Trust publication, entitled “Information Relative to the Port”. This map is almost certainly an amended version of one compiled during the 1880s, and is based on a raft of discreet land surveys, each of them referenced to a local ‘flat-earth’ datum. The map was scanned at a resolution of 400 dpi.

3. The photographic images contained for each year scans were simultaneously orthorectified using Erdas Imagine 8.6 image processing software. The Erdas package contains a module called “Orthobase Pro”, which is specifically designed to allow “bundle adjustments” of the kind needed to process image data with geo-referenceable pixels. The process requires us to enter certain pre-determined information, which includes:

   A. Particulars pertaining to the camera and lens used in the project. (Copies of the original camera calibration reports are available from the supplier in most cases.)

   B. Ground Control Points (GCPs), which can be identified on the images and for which we know the X, Y and Z coordinates. A minimum of three GCPs per image is required. In this instance we determined eastings and northings (X and Y) of street intersections from a preexisting vector database of roads in the municipality. For our Z values we used a digital elevation model (DEM) based on the 1:25000 topographic map series. The GCPs provide absolute coordination of the block with respect to a generic or external datum, in this case the Australian Map Grid, Zone 55 (AMG.)

   C. Once all the GCPs had been appointed, a function called 'Automatic Tie-point Extraction' was used to improve relative coordination between the images. An automated technique called 'Triangulation' was then used to compute new X, Y and Z values for every pixel in all images. The process involves constructing a lattice of triangles across the study area, of such dimensions that all the rigid conditions pre-established by the tie-points and GCPs are satisfied. The acceptable Root Mean Square Error (RMSE) for a mosaic of 4 photos was around 0.3, for eight photos around 0.7, for twelve photos around 1.0 and for twelve or more photos around 1.5 to 1.7.
D. The images were now subjected to a process called ‘resampling’. This involves adjustments to the graphic status of all pixels in the images, as determined by the triangulation.

The above processes were executed twice, once for each of the 1942 and 2001 projects.

4. The orthorectified images were digitally mosaicked in the Erdas environment. Because standard overlap exists between sequential images (typically 30% between runs and 60% between photos along a run) there is redundant imagery away from the image centres, the less preferred of which can be jettisoned through manual determination of ‘cut-lines’ (the line along which two contiguous image sections abut one another.) After mosaicking, all the data was contained in two image files. The 1942 file is around 100 MB in size, while the 2001 file, being in colour, is of size 300 MB.

5. The mosaics were subjected to various tonal adjustments, making them as visually ‘seamless’ as possible. These adjustments compensate for the fact that identical features on adjacent images will have different tonal values due to relative foreshortening of shadows between imaging positions.

6. The Harbor Trust paper map was divided into four sections, corresponding with the northwest, northeast, southeast and southwest quadrants. These were treated in similar fashion to the photographs, using Orthobase Pro, but presuming a non-metric ‘camera’ type. The corrected quadrants were mosaicked to create an output map sufficiently consistent in both orientation and scale, to be collated with orthorectified photomosaics. (Note that a better result could have been achieved, had we subdivided the original map into eight or sixteen parts.)

7. A generic empty map window was created using ArcGIS 8.3 software, which linked the rectified map and the two mosaics. This permitted time-sequence overlays of data from the different years, each of which corresponds to a separate ‘layer’.

8. Pre-vectorised land parcel data from the current Digital Cadastre Map Base was incorporated, forming a fourth layer.

9. Portion of a second Harbor Trust map, this one from 1890, was registered to the 1910 mosaic. Note that the geometric fidelity of this layer is, by virtue of origin, limited by the fidelity of the 1910 layer.

10. Selected early MMBW maps (showing the Sandridge Lagoon area) were scanned and registered to the DCMB.

11. ‘Coverage’ layers were created in ArcGIS, one for each of the focus years. Using these layers, features from the mosaics were assigned to broad land-use classes, (water, swamp, buildings, gasworks and so on). This was done by tracing digital polygons (assigned to the coverage layers) over displays of the mosaics. Attribute tables containing specific information were attached to each polygon.

12. A ‘grid layer’ was constructed, showing AMG eastings and northings. When displayed, this assists the location of historic buildings, swamps, landforms etc, in the context of the modern land-cover and parcelation.
A flow chart illustrated in Table 2 briefly describes the steps involved in making an orthophoto mosaic for one year in the City of Maribyrnong. Estimates of how much time it took and the accuracy considerations for the acceptance to the project are summarised. Similar methodology was used in this study of the Melbourne Harbour-side study area.

**MELBOURNE HARBOUR-SIDE LAND PARCEL LAND-USE CHANGES OF SIGNIFICANCE IN RE-DEVELOPMENT PLANNING PERMIT APPRAISAL**

The Melbourne Harbor Trust was convened in the year 1877, to manage and implement improvements to the young city's port and shipping facilities. Its first major initiative was to enlist the services of Sir John Coode, one of England’s foremost engineers, to provide a visionary framework for the improvement and modernization of the port. Coode was engaged at a cost of 5000 guineas, and arrived in Melbourne on February 2nd 1878. His close personal inspection of all existent survey plans, engineering reports, proposals and the proceedings of commissions was followed with a request for "an exhaustive series of levels, borings and soundings" (Hoare 1927, p. 28).

Coode's report was received in April 1879, and the Trust resolved that it should be adopted as policy, after three weeks' consideration. Among the report’s numerous recommendations were:

1. The filling of the Sandridge Lagoon
2. The construction of a shipping canal across the land known as 'Fisherman's Bend'
3. The construction of three docks, "furnished with all the usual accessories, modern appliances, and placed as close as practicable to that part of the city which is occupied by the large mercantile establishments, and also to the chief railway terminus of the colony" (Hoare 1927, p. 29).
4. Using the database we have built, it is possible to trace the progress of Coode's recommendations, along with subsequent changes, all of which contributed to a radical alteration to the 'face' of Melbourne's docks.
The Sandridge Lagoon, which was later called the Port Melbourne Lagoon, was a source of considerable nuisance and expense to the Melbourne Harbor Trust, throughout its first 50 years of operation. The lagoon originally extended inland for some 1.3 kilometres, to the south side of Raglan Street in Port Melbourne. It acted as a cesspool, receiving all the runoff from the streets of South Melbourne and Port Melbourne. Its stagnant waters were the source of foul odours, and served as a breeding ground for noxious algae and bacteria.

By 1879 filling had progressed from the lagoon's original inland extremity to as far as Bridge Street Port Melbourne, (Figure 4), but the remainder continued to catch the drainage from the surrounding poorly sanitised suburbs. One must remember that in the 1870s and 80s Melbourne's sewerage system was lamentably undeveloped. One estimate put the number of cesspits in the built-up area at over 3000, and it was common for human and animal faeces, rotting meat, tallow and food scraps to lie about the street in great reeking puddles (Cannon 1976, pp. 156–160). The Trust asked the councils of Emerald Hill and Sandridge to divert runoff from the lagoon via specially constructed channels leading directly into the bay. In return it proposed to dredge the lagoon, making it navigable and accessible to craft from the open sea. When the councils declined to act in this regard the Trust resolved to fill the remainder of the lagoon, according to Sir John Coode's recommendation (Hoare 1927, p. 36). No action was taken toward this objective however, for the time being.

The problem returned to the Trust's agenda in 1885, with the formal invitation of proposals for alleviation of the stench and inconvenience (Hoare 1927, p. 97). Two alternative schemes were vetted that following year. The first involved filling up the lagoon, as had been originally proposed by Sir John Coode, and leaving a narrow channel in its place for the carriage of the Sandridge and South Melbourne waste. The second proposal was to deepen the lagoon, so as to "thoroughly remove all of the foul deposit therein", and the concurrent diversion of all drainage via two pitched channels to either immediate side of the waterway. A third proposal, involving the discharge of drainage into the lagoon after its treatment with chemical disinfectants, was rejected outright' (Hoare 1927, p. 98).

The Harbor Trust, in association with the Government, reached an agreement on July 7th 1886. The chosen plan was to preserve that portion of lagoon lying between the Port Phillip Bay and Graham Street, and to divert all drainage, via a single channel, from this section. The Trust would oversee the dredging of the section between Rouse and Graham streets, to a depth consistent with that portion between Rouse Street and the bay. This work was only part done, and sanitary problems remained substantially unchecked (Hoare 1927, p. 99).

In 1888 the matter was revived by a letter from the Chief Secretary, asking the Trust to agree to a scheme for filling a further portion of the lagoon. The overall scheme was to cost £46000, of which the Trust was to contribute £5000. In return, the Trust's Commissioners promised the Government, along with the municipalities of Port and South Melbourne, to build a navigable entrance to the lagoon, dredged to a depth of 6 ft, as far inland as the Rouse Street Bridge. A considerable deal of debate transpired during this period, over the issue of cost sharing between the Government and the Trust. To some extent, the Government appears to have tried to cajole the Trust into contributing to the works, with threats of greater liability for expenditure arising from non-agreement (Hoare 1927, p. 99).
Sandridge, circa 1880

Showing the original lagoon (marked 'in the course of reclamation') extending inland as far as Bridge Street, Port Melbourne.
(Sourced from Melbourne Harbour Trust Annual Report, 1910)

Sandridge, circa 1920

By about 1920, the lagoon had been filled to as far as Rouse Street, Port Melbourne. The only remaining portion is a reinforced canal. Note the major gasworks, to the immediate east of the filled lagoon.
(Sourced from archival MMBV map (scale 1:1520)).

Figures 4 and 5. Sandridge, circa 1880 and 1920
By 1942, the lagoon had been completely reclaimed, and some housing development had taken place on the filled ground.

Today, all filled land lying southwest of Graham Street Port Melbourne has been built upon. This development includes multi-storey apartment blocks. Note also, redevelopment at the old gasworks site.

**Figures 6 and 7.** Sandridge, 1942 and 2002
On June 26th 1888 the Borough Council of Port Melbourne applied to have the piece of land adjoining the western pier at the entrance to the lagoon filled up, "as in its present condition it was highly prejudicial to health" (Hoare 1927, p100). This land was situated between Beach and Rouse streets, and its eastern boundary was the pier at the western entrance to the lagoon. The filled land was a proclaimed street known as "Esplanade West'. Thus by the end of 1889, the lagoon had been 70% filled.

For years the remaining portion continued to create friction between the Melbourne Harbor Trust and the municipality of Port Melbourne. In 1923 an agreement was finally reached to fill it, and for the construction of a road link between Bay and Johnson streets in Port Melbourne' (Hoare 1927, p376).

Pursuant to this agreement, the Trust agreed to:

1. Construct reinforced concrete piling across the lagoon
2. Demolish the wharf inside the sheet piling line
3. Divert existing storm water so that it would discharge on the shoreline.

The Council agreed to:

1. Reclaim the area inside the sheet piling
2. Build a road from Bay Street to Johnson Street, with a retaining wall along the sea frontage, now part of Beaconsfield Parade.
3. Amend the Trust’s boundary to include the reclaimed land.

Figures 4-7 show the Sandridge precinct at various dates. The view from circa 1880, taken from an archival map, which has been corrected for distortion and georeferenced, shows the lagoon extending inland to as far as Bridge Street Port Melbourne, and marked ‘in course of reclamation’. Figure 5, taken from a Melbourne Metropolitan Board of Works (MMBW) map from about 1920, shows the lagoon filled to as far as Rouse Street Port Melbourne. The sole remaining portion is a reinforced canal, with an artificial entrance extending some distance into Port Phillip Bay.

By 1942, (Figure 6), the lagoon has been completely reclaimed, and some housing development has taken place on the filled ground between Esplanade West and Esplanade East, Port Melbourne. About 50 percent of the filled ground remains barren land. The sea barriers that marked the entrance to the now filled canal have fallen into disrepair, but are still discernable.

By 2002, (Figure 7), the all the filled land lying southwest of Graham Street, Port Melbourne, has been built upon. (This development includes two multi-level apartment blocks, ‘The Port’ and “HMAS Apartments’). One of the walls at the entrance of the now filled canal appears to have been restored.

Figure 8 shows the outline of the lagoon in about 1880, superimposed upon the 2002 mosaic. Clearly, a number of constructions have taken place on filled ground. Hopefully, the lessons of such spectacular development failures as the Yarraville Sinking Village (Peterson et al. 1977 and Luxford et al. 2003) and inspired scrutiny of the geotechnical computations and soil toxicity accompanied their development permit appraisal.

(B) THE COODE CANAL

The Melbourne Harbor Trust was ready to commence cutting Coode’s proposed channel across Fisherman’s Bend by the middle of 1879. The original canal was to be 2000 ft long, 300 ft wide and 25 ft deep, and was estimated to cost £476,400. (Hoare 1927, p. 32). Two hundred and twenty-nine acres were reserved for the excavation in 1880, and the Government organised the commencement of digging as part of a relief scheme for the unemployed. The soil taken out was used to reclaim low land on the riverbank (p. 32). Excavation progressed for six years, and on September 9th 1886 the sluices were opened by his Excellency the Governor, Sir Henry Brougham Loch. The canal was full by September 17th, and officially opened to the public on July 27th 1877.

The canal was dredged for the first time in 1890, when the deposit of silt was found, in places, to be four feet (1.22m) deep (Hoare 1927, p. 132). During 1905, rules governing the passage of shipping within the canal were passed, giving right of way to craft sailing from Melbourne out toward the bay (p. 255).

The canal was found to be too narrow, and a plan to widen and deepen it was resolved by Harbor Trust commissioners in April 1906. The Department of Public Works undertook the removal of ‘dry’ material, whilst the Works, Dredging and Stores Committee was charged with removing all other matter. A steam hopper barge of 600 tons was engaged to assist with the
dredging. This ship arrived in Melbourne in April 1907, and was named the 'William Pitt' (Hoare 1927, p. 234).

**Coode Island and canal, circa 1910**

![Diagram of Coode Island and canal, circa 1910](image1)

Before canal widening, river reclamation and the construction of Swanson Dock, Coode Island was truly an island. Beyond the original course of the River Yarra spread the undeveloped expanse of West Melbourne Swamp.

**Coode Island and canal, 1942**

![Diagram of Coode Island and canal, 1942](image2)

By 1942, both West Melbourne Swamp and the Yarra River's original course had been extensively filled. The Coode Canal, though somewhat wider than in 1910, was still relatively narrow.

*Figures 9 and 10. Coode Island, circa 1910 and 1942*
Widening work commenced in July 1906, and some 220,000 cubic yards had been excavated by the end of 1907. By the end of 1908, 355,000 cubic yards had been removed. The spoil was
dumped on low-lying crown lands. By the end of 1910 the work was still unfinished, but neared completion. The widening increased the channel's width from 266 to 430 feet (81m-131m), which equated to a bed width of 270 feet (82.3m) given a depth of 26 2/3 feet (8.12m), and wall slopes of 1 in 3 (Hoare 1927, p. 234).

Figure 9 shows the Coode canal, along with the original course of the Yarra River and some of the West Melbourne Swamp, in 1910. Note the overlying grid of AMG eastings and northings, which can be included by virtue of the georeferencing. This allows features appearing on older (orthorectified) images to be traced onto the modern landscape.

Figure 10 shows the same area in 1942. Note that only part of the canal retains its 1910 width, and that approximately 650 metres of the Yarra River's original course has been filled. Note also how the West Melbourne Swamp has been extensively reclaimed, and how much the remaining marshland has been divided into a lattice of ponds.

Figure 11 shows the area in 2002, by which time the river's old arm had vanished, and Swanson Dock, (created between 1966 and 1972), bisected the land formerly known as Coode Island. Note also, how the West Melbourne Swamp has been completely reclaimed, and now hosts a mixture of industrial and commercial land use, including the Melbourne Fish Market and Wholesale Fruit and Vegetable Market. Note also the extensive widening of what was once the Coode Canal, to accommodate the larger shipping necessary in this age of 'containerisation'.

Imposition of the modern cadastre on the 1910 feature polygons, (Figure 12), allows us to assess which land parcels overlie reclaimed land. The 'filled land' status of land parcels is an important component of their identity, and is of potential interest to prospective buyers, vendors, leaseholders, planners, developers and litigators.

(C) THE VICTORIA DOCK

In his 1879 report, Coode recommended that the only viable position for Melbourne's new docking facilities was the eastern part of West Melbourne Swamp. His original plan showed three separate docks, known respectively as docks No.1, No. 2 and No. 3. Dock No. 1 was alone forecast to cost £646400, and to require the removal of 1.25 million cubic yards of material.

Coode had proposed that the main walls to the docks be constructed of concrete and stone (Hoare 1927, p. 28), but in 1883 it was suggested by Resident Engineer Joseph Brady that timber should be used instead. The rationale for this was the high expense of concrete, and the shortage of materials. Under Brady's alternative, the cost of No. 1 Dock was £342225 – little more than half that of Coode's original proposal. Further to this, Brady argued, the cost of completely re-plenishing the dock walls at fifteen year intervals would be considerably less than the interest earned by money originally saved through not using concrete, assuming the current interest rate (Hoare 1927, p. 75).

Brady's proposal received serious consideration from the Harbor Trust commissioners, and comment was sought from Sir John Coode. Coode was absent from England at the time, but his associate recommended sticking to the original plan. Notwithstanding this, the Trust resolved, after months of consideration, to investigate the Brady alternative more thoroughly. The plans had, by this stage, been considerably honed and modified. Most notable among the changes introduced was a proposal to incorporate docks 1, 2 and 3 into the one complex. This, it was said, would provide a facility with a surface area of 70 acres, and a berthing space of 16500 feet, sufficient for 53 large ships. The total quantity of dredging would be 3,000,000 cubic yards.
Wharf edges would consist of ironbark, red gum and jarrah timbers. Comment was again invited from Sir John Coode, and the project was suspended in 1885, pending his reply (Hoare 1927, p. 75).

By January 1972, formerly barren, swampy land to the north of Victoria Dock had been built up and hosted a mixture of industries.

The last decade has witnessed construction of Colonial Stadium, City Link and residential developments upon the dock’s edge. Note the construction of apartments, in progress at the time of this image, upon the former gasworks site to the dock’s south.
Coode's reply came in May 1886. He reiterated (and, in fact, emphasized) his original preference for concrete and stone walls, citing as evidence recent indicators as to the instability of sub-surface materials in the West Melbourne Swamp. He concurred with Brady however, in his opinion that the three docks as originally proposed should be incorporated, and that the depth of the resultant should be 27 feet (Hoare 1927, pp. 102–112). After further consideration, the Trust decided to adopt Brady’s recommendation as to timber wharfage, solely on the issue of cost. The first contracts for the work were signed on May 11th 1887.

Work started on the dock on April 16th 1889, and was finished in July 1891. By this stage it was known as 'West Melbourne Dock'. In eventuality, a total of 3,114,808 cubic yards of material were removed, and subsequently used to fill Harbor Trust and Railway Department land, along with parts of the West Melbourne Swamp. The final expanse of the dock measured 96 acres. It was opened to the waters of the Yarra via activation of a sluice valve, on March 22nd 1892, by his Excellency the Governor, the Earl of Hopetoun. The dock filled up during the following 6 days, and there was "great jubilation" on the wharves (Hoare 1927, p. 151).

The entire wharf along the northeast side of the dock, and 1500 feet of wharf along the northwest side were widened considerably, from 40 to 100 feet, during 1912 and 1913. Two huge sheds, measuring 600 by 60 feet each, were built along the northeast side (Hoare 1927, p. 296). On December 4th 1914, the Commissioners accepted a tender for the construction of a central pier in the dock, 1630 feet long by 250 feet wide, with a roadway down its centre. This pier was to contain six cargo sheds, each of them measuring 486 by 60 feet, and would provide six additional shipping berths. The work, with an expected cost of £228000, progressed throughout 1915, and was completed during 1916 (Hoare 1927, p. 296).

Figure 13 shows Victoria Dock in 1910. Note the absence of the central pier, which was yet to be built at this stage. Figure 14 shows same scene in 1942. The central pier is prominent, and there are 12 ships at dock. The dock’s entrance is still relatively narrow, but the river south and west of the dock has been significantly widened.

Figures 15 and 16 show the dock in 1972 and 2002 respectively. Note the reduction, by 2002, in the area of the central pier, along with construction of the Bolte Bridge and Colonial Stadium. Note also how various projects in the 'Docklands' and 'Yarra Quay' developments were in the mid phase of construction, and how the Yarra banks closer to the city are spanned by more and more bridges, reflecting their reduced importance to shipping, as wharfing is concentrated further downstream.

**EXEMPLIFYING POTENTIAL TIME-SERIES SPATIAL DATABASE APPLICATIONS**

**A) LOCATION OF HISTORIC RUINS**

Figure 17 shows the outline of buildings, piers and riverbank at Fishermans Bend in about 1920, superimposed upon a photomosaic from 2002. Such display provides a guide as to where somebody interested in locating the remnants of historical features in the context of the modern land cover should excavate. Figure 18 is an enlargement of the view, showing the location of buildings belonging to the old aircraft factory, pre-World War 2. The Australian Map Grid (AMG) eastings and northings coordinates of building corners, which are read directly from the database, can be input to an uploadable file for precise location using total station or a roving GPS receiver.
This has considerable potential to maximize the economy of operations, (i.e., digging in the right place), and also to minimize the risk of disturbance of sensitive sites and the damage to artifacts of historical significance.

1920 buildings and river on 2002 mosaic

Six small jetties lined the riverbank, adjacent to the Commonwealth Aircraft Factory buildings, early last century. The position of the riverbank on this southeast side has scarcely changed, but the opposite bank has has shifted significantly.

Enlargement, showing AMG coords of historical building corners

AMG coordinates of historical building corners can form the basis of an uploadable file, to assist the precise location of artefacts in the field.

Figures 17 and 18. Mosaic and AMG coordinates
It is likely that the features chosen for this example would be of little historical interest; nonetheless, the approach has potential to assist archaeological endeavours at sites of considerable significance, such as the 2002 dig, conducted by Heritage Victoria, at colonial Melbourne’s ‘red light’ district, off Little Lonsdale Street (The Age 19/7/2002, p3), Mayne et al. 2000 and the 2001 archaeological survey at the Panorama Motel site, at Port Macquarie NSW, which located the complete footings of the 1821 Government House (The Sydney Morning Herald p 10, 24/3/2001).

**B) IN RE-DEVELOPMENT PLANNING PERMIT APPRAISAL**

Obviously, at the time the permit to build the Yaraville sinking units (Peterson et al. 1977 and Luxford et al. 2003) was issued, the tools now used for digital image processing and spatial analysis were not available. While this fact doesn’t absolve the council of negligence, (the critical 1931 and 1945 airphotos did exist in 1970 when the permit to make units was given), a similar mistake today, with the suite of technology now available, would be far less excusable.

With the benefit of the kind of time series spatial database we have exemplified above, one would expect a planner in a local government office to quickly take note of the former quarry. Based on several observations of the quarry hole as shown by the time-series mosaic, enquiry could then be made as to who managed the land at the time the hole was filled, and what fill materials were used. This investigation may commence with a perusal of rates notices, title and survey documents in the council’s own archives.

| Re-development Permit Application | YES |
| Meet Statutory Planning regulations | NO |
| Contaminated Ground or Filled Ground? | YES |
| Buried Heritage | NO |
| EIA Accepted | NO |
| Referral Authorities | REJECT |
| Advertise if required | |
| Objections | YES |
| Issue Permits | |
| Redraft Application | |
| Fast Track? | YES |
| Appeal? Negotiate? | NO |
| Decision | YES |
| Deny Permit | |

**Table 3.** A generalised re-development permit application appraisal path and the application of time-series land parcel history for decision support in permit approval

In view of the known settling patterns and behaviour of the fill material over time, a list of recommendations could be made upon which a development permit is conditional. These might
include the grid-based drilling of cores and digging of test pits to determine a suitable location for building envelopes and/or the carrying out of substantial compacting works and the placing of additional fill over the site i.e., all those measures taken retrospectively at the Yaraville Sinking Village site. Any such drilling and digging can be directed on the basis of our knowledge as to the dimensions and location of the filled pit, (as viewed and measured from the time-series database). This improves speed and economy of urban re-development projects.

Table 3 shows a generalised re-development permit application appraisal path and the application of time-series land parcel history for decision support in permit approval.

CONCLUSIONS

The information technology revolution offers unprecedented opportunity for a convergence of disciplines involved with spatial data. Never before has the planner had at his/her disposal so comprehensive a set of tools for the analysis, storage and geo-referencing of data. And never before have had so many exciting opportunities, or such justification, existed for a spatial analyst to apply his/her science to history. Such a State wide temporal database of aerial photo archives will contribute as one of the key datasets to the Victorian Spatial Data Infrastructure (SDI) which is essential to the needs of diverse decision making environments (Feeney 2001).

Even with the benefit of today’s technology the registration of diverse input datasets to a common reference grid and projection is only achievable through a sequence of complex, time-consuming procedures. Often the initial results are dubious, and the process becomes experimental. Results achieved pragmatically need to be quality assessed against precise vector or more rigorously obtained raster datasets, themselves not available prior to the digital age.

The spatial database explained here is very much an application in the digital age. Until recently the means, with regard to software, hardware, and relevant expertise, was not available for its assembly. In light of this, it seems ironic that those very raw constituents of most importance to the spatial database have been present for considerable amounts of time, many of them since before federation of the colonies. It is lamentable that certain of them, the earliest air photos in particular, have not been treated with the level of respect befitting so rich and significant a resource. It is to be hoped that these circumstances will change with the increasing adoption and fruitful application of the time-series spatial database, in a range of areas.

The time-series spatial database is useful at a range of levels, in a host of applications. At single parcel level, it enables the assessment of re-development and, in some cases, public health (eg see Kolodziej et al. 2004) hazards, maximises the economy of excavation and salvage operations, and minimises the risk of artifact damage. On a wider scale, it endows the planner, geographer, historian or social researcher with means to conduct an unprecedented appraisal of broad landscape change over time, (from swamp to port, from port to city and so on), which, because this is a quantifiable illustration of history is, and will remain to be to be, of critical interest.

RESOURCES

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