


CONDITION ASSESSMENT: WORKING WITH INFORMATION

Recording Streetscapes

Salim Elwazani and José Luis Lerma

The Qayseriyyah Souq (market) is a historic ensemble of urban structures in Muharraq, the original capital city of Bahrain. Besides the evident buildings and open spaces of the souq, the ensemble is in an area long considered a cradle of societal transformation and political events in Bahrain's history. Exposed to the elements, neglect, and inappropriate building additions and development, the souq has deteriorated. In 2005, a preliminary study was conducted to assess the souq in order to address these issues.

Under stringent time and financial constraints, how can the souq be recorded quickly to provide information to aid in its revival and conservation?

The corner of Sheikh Hamad Avenue and Tujjar Street, Qayseriyyah Souq, in the heart of Muharraq, Bahrain. The souq suffers from exposure to the natural elements, neglect, and inappropriate development. Photo: © Salim Elwazani and José Luis Lerma.

Qayseriyyah Souq, Bahrain

The Qayseriyyah Souq sits in the heart of Muharraq, the sprawling commercial center of the old capital. History suggests that the construction of Muharraq was at the behest of Sheikh Ahmed Bin Mohammed Al-Khalifa, also known as Ahmed Al Fateh (the Conqueror), in 1810. Later, tribal groups, some formerly nomadic, emigrated from Arabia under the leadership of the Khalifa dynasty and settled in this new place. In a societal sense, the souq is a testimony to this transformation of the inhabitants' way of life and a direct response to their commercial needs. By 1889, urbanization had reached an advanced stage and many of the physical characteristics of the souq seen today had been established.

Roughly rectangular in shape and stretching in a north–south direction, the souq is bounded by paths of contrasting urban character. On the north, the busy, dominant city artery known as Sheikh Hamad Avenue contrasts with a modest pedestrian alley on the south. Traffic-burdened and commercially bustling Tujjar Street, on the west, contrasts with the spacious, lightly trafficked Boomaher Avenue on the east. About 80 meters in length and 30 meters in width, the souq is composed of rather simple one- and two-story structures. The market features a covered central alley running north–south along the ground plan that, with another auxiliary alley, bisects the souq into four parts. This central alley and, to a lesser extent, the auxiliary alley provide access to the inward-facing shops, while the bounding avenues provide access to the outward-facing businesses and upper levels.

The buildings are made primarily of rubble, gravel, and gypsum cement. Wooden members, reed rods, and palm-leaf weaves were used for the roof structures and ceilings. The conditions of the structures within the souq vary markedly, but the buildings are generally in disrepair. The souq suffers from exposure to the natural elements and neglect, and from inappropriate development that affects the integrity of the architectural character. Three-fifths of the buildings have retained their original character and are more than fifty years old, with many estimated to be more than one hundred years old. Vestiges of these important older buildings now predominate only in the poorest and most dilapidated sections of the market. The remaining two-fifths of the buildings have been erected within the past fifty years. It is clear that this newer, historically incongruent class of buildings, particularly those erected in the past decade, are slowly replacing the original structures. A sizable vacant lot within the market clearly shows traces of an original structure that probably was demolished to make way for new construction.

Not only are the still-visible original buildings at risk, but archaeological vestiges also are said to be buried within the souq, including remnants of a historic city wall. Ahmed Al Fateh had decreed that walls be built with three gates. One hypothesis suggests that one of these walls was subsequently adapted as a foundation for buildings at the eastern edge of the souq. A city gate also may have been integrated into the buildings at the northeastern corner of the market.

Map of the Qayseriyyah Souq, showing major avenue boundaries, central and auxiliary alleys, and building components of heritage value. Not only are the original visible buildings at risk, but archaeological vestiges are said to be buried within the souq. Map: Steven Rampton.

Rectified Photography

Realizing the risks to the souq and its importance, the Research and Studies Section of Bahrain's Ministry of Municipalities and Agriculture Affairs conducted a preliminary study for conservation and development. The ministry then commissioned a consultant as project manager to prepare a detailed, implementation-oriented redesign of the souq, taking into consideration conservation issues and urban integration of the historic fabric with the modern surrounding city. This project was one component of a larger, two-phase pilot project, Capacity Building for Enhancement of Urban Governance, funded by the United Nations Development Programme and implemented in collaboration with Bahrain's Ministry of Municipalities and Agriculture Affairs.

Although site plans of the market existed, the project manager lacked information on individual building facades and the extended streetscapes. In order to understand and propose strategies for this complex marketplace, it was necessary to obtain additional information. Facing limited time and financial resources, as this was only a preliminary study, the project manager and a small team composed of the authors and four junior architects were tasked with this work.

The team chose rectified photography for the Qayseriyyah Souq project because it is inexpensive and quick to carry out, requires minimal training, and does not require high-tech equipment. In addition, the resulting images of each building facade could be later converted into measured drawings. Rectified photography is based on the concept of bringing the surface of an object, say a building facade, and the plane of the image (photograph) into parallel. Rectification removes

Unrectified photograph of a storefront, taken at an angle. Photo: © Salim Elwazani and José Luis Lerma.

Rectified photograph of the same storefront. Rectification removes perspective, angle, and camera lens distortion to create an image that is on one plane and measurable. Photo: © Salim Elwazani and José Luis Lerma.

Mosaic of Souq West elevation on Tujjar Street.
Photos: © Salim Elwazani and José Luis Lerma.

Mosaic of Souq North elevation on Sheikh Hamad Avenue.
Photos: © Salim Elwazani and José Luis Lerma.

perspective, angle, and camera lens distortion, and creates a measurable image that is on the same plane as the building. This method is the most appropriate when the building surface is geometrically flat. Buildings having multiple flat surfaces positioned in different planes can also be rectified: each plane is separately rectified, then brought into one reference plane. Rectified imagery worked particularly well in the souq, as the building facades are relatively flat and images had to be taken at extreme angles with a wide-angle lens in the narrow streets and alleys.

Image rectification can be carried out with or without measurement control points on the object. Control points can be measured using a tape measure or with survey instruments (total station). These measured distances correct the angle or tilt in the original image while retaining the correct proportions of the building. Without these control points, it is still possible to rectify an image by visually approximating its shape and proportions; however, accuracy is compromised.

Rectified images have several advantages in the field of architecture, urban planning, and conservation. Not only do they provide measurable images of flat surfaces that show surface material conditions, but they also can be stitched together to form an entire facade elevation of a large building or several adjacent buildings. Other recording tools, such as a total station or stereophotogrammetry, can provide some of these results; however, they are time consuming and somewhat expensive, and require specialized training.

Constrained by the limited time available to deliver a final product (only twelve days total, including training for the junior architects), the project manager was asked to prioritize the areas needed for rectified photography. In addition to the immediate area of the souq, he chose several adjacent street scenes for their value and impact on the overall study, resulting in an even tighter time frame to accomplish the work. The team decided to divide the work into three parts: images to be rectified, images that could be rectified in the future, and pictorial photographs not to be rectified but to provide context.

The project began with a day of touring and exploring the souq with the directors of the participating organizations and the project manager. For five days, images were captured and building measurements taken. Then, in the time remaining, images were rectified. The team prepared a final report and collaborated with the project manager on his preliminary study. The junior architects received training throughout the entire process of acquiring and processing the data.

An Answer

Images were captured using a Canon EOS D60 digital camera with a resolution of 6.3 megapixels and a 15mm Sigma wide-angle lens mounted on a small tripod. Image capture was initiated from across the street at one end of the building row, typically coinciding with a street corner. As the photographer moved toward the other end of the building row, a series of digital images was captured in such a way as to maintain an overlap of 20 to 30 percent between images of adjacent buildings. The team also emphasized the continuity of the linear “scene,” including empty lots, alleys, and objects between buildings. This type of information was as important as the buildings in order to assess the souq and carry out the preliminary study in an urban environment.

Uniform lighting conditions were taken into account, as well as precautions such as avoiding photography of moving objects in front of the facades. Multiple frames of the same areas were taken in order to ensure complete coverage and to capture enough detail. Care was also taken to keep the camera level, and attempts were made to maintain a uniform distance perpendicular to the buildings. These measures later minimized corrections to the rectification process. While collecting the images, the team also took several horizontal and vertical measurements of the buildings by hand, noting significant features to be used as control points.

In this case, the camera’s automatic image numbering system was used as the identifier for each image, correlated by hand on a map of the souq. This linkage enabled the retrieval, selection, arrangement, and measurement of the series of sequential images. Rectification of selected images was carried out in a repetitive, structured procedure using Adobe Photoshop CS2 (Creative Suite). The procedure began by rectifying a series of adjacent images of each separate building facade, using the souq map and the measurements taken in the field. Using the overlap between images, individual rectified images were then fused into a combined image called a mosaic. This process produced a new, expanded mosaic of the entire streetscape. Color processing was necessary in order to maintain some homogeneity throughout the composition. Panorama Tools, a free plug-in added to Adobe Photoshop CS2, was also used to correct lens distortion. Adobe Photoshop CS2 software has a special filter called Lens Correction that performs the same correction function.

The team strove to establish a rate of progress that would help the project manager realistically estimate the amount of work that could be accomplished in a given time. The documentation process resulted in more than two hundred images, of which twenty-six were rectified and combined to produce mosaic streetscapes of the souq. It also resulted in some general context images, but more important, it yielded more than one hundred fifty images that could be rectified in the future, an important consideration given the limited time available for the preliminary study. The pace of the work was rapid, as it was unclear from the outset how fast the photography and rectification would proceed.

Although more work is required, rectified photography provided the project manager, the city, and the ministry with another dimension to the Qayseriyyah Souq beyond the site plan and single unrectified images. It allowed the streetscapes to be viewed in their entirety in a measurable, organized way to improve conservation planning and design.

The parties involved also sensed the potential value of continuing the work beyond the souq and enriching their presentation and reports.

The photo rectification work also fulfilled the needs of the larger project with future capacity building through the training of the junior architects. While the training component was intense and time consuming, and distracted somewhat from the primary goal of recording the facades of the souq, it was a valuable exercise that holds promise for future projects. The junior architects formed the nucleus for continuing the work and creating additional streetscapes of the souq as well as other sections of the city. To reap additional benefits, another training program should be initiated to include other tools beyond rectified photography.

The digital rectified images and combined mosaic images also provide a lasting, measurable record of the Qayseriyyah Souq as rapid changes take place even today.

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Condition Survey

Rand Eppich, Dusan Stulik, and Jaroslav Zastoupil

Over the centuries, the vividly colored images and figures of the *Last Judgment* mosaic, on the southern facade of St. Vitus Cathedral, in Prague, Czech Republic, have been obscured by a gray crust. Before conservators could begin to restore the mosaic, they needed to study the types and locations of damage, previous treatments, and other problems. Graphic documentation enables conservators to record their studies and note conditions. Technology should assist, not interfere, with this process.

How can conservators record these conditions using simple techniques yet still harness the power of technology?

Detail of an angel, shown after cleaning, in the *Last Judgment* mosaic, above the entrance to St. Vitus Cathedral, Prague. Photo: Dusan Stulik.

St. Vitus Cathedral, Prague

Jesus Christ, the central figure in the *Last Judgment* mosaic, is depicted passing judgment on the world, surrounded by triumphant angels above the patron saints of Bohemia. To his right, the dead are resurrected from their graves. To his left, blue devils welcome the damned. These dramatic scenes have become visible only recently. For hundreds of years, they were obscured by a chalky gray crust caused by the corrosion of the small glass cubes, or tesserae, that make up the mosaic. The corrosion was the result of rainwater interacting with the impurities of potassium and calcium within the medieval glass. When exposed to water, these minerals are leached out, creating alkaline salts that react with carbon dioxide and sulfur dioxide and crystallize on the surface.

It is likely that Charles IV, king of Bohemia and the Holy Roman Emperor, noticed the "dimming" of his mosaic. He commissioned the work in 1371 for the southern entrance of the cathedral to symbolize the magnificence of his kingdom. Called the Golden Gate, as much of it was gilded, the mosaic is made of more than a million red, blue, and other brilliantly colored tesserae. It is composed of three panels 4 meters wide by 8 meters high, and is considered to be the most important mosaic north of the Alps. Cleaning and repairs had been attempted several times over the centuries but always with short-term results, and the mosaic soon became obscured again.

In 1992, the Office of the President of the Czech Republic, the Prague Castle Administration, and the Getty Conservation Institute (GCI) began a project to conserve the mosaic and make it permanently visible. An expert conservation team was formed with leading conservators, historians, and scientists from across Europe and the United States. They were presented with three significant challenges: to determine what caused the crust, to safely clean the glass without damaging it, and to protect the work from the elements once cleaned.

The ten-year project was divided into four phases. First, conservators studied and researched the mosaic's history, past treatments, and physical composition to identify and describe the mechanisms of deterioration. Second, they examined and assessed its current condition, documenting in detail the levels of corrosion, cracks, missing tesserae, original traces of gilding, previous interventions, and other significant attributes. This was followed by the third phase, extensive testing of treatments for both cleaning and protection. Conservation was implemented in the final phase once the team was absolutely sure of a safe and effective treatment. After conservation was finished, the mosaic was periodically monitored to ensure that it remained visible.

Constraints on the project were few, as this is a significant work of art and a national treasure. However, there was one significant constraint concerning documentation during the second phase. Project managers wanted to use advanced computer imagery and graphics to record and analyze the information collected on the mosaic, yet expert conservators on the team had never used this technology. The managers insisted that conservators should not have to alter their methods or compromise their condition assessment. An approach had to be developed so that the conservators could collect data on site, yet still use computer technology for analysis, investigation, and publication.

Detail of a figure in the mosaic prior to cleaning, showing levels of corrosion. Photo: Dusan Stulik.

Transparencies

A simple but systematic method was devised using multiple A4-size transparent plastic sheets over printed images of the mosaic. By using this method, conservators were not distracted by technology and did not have to substantially change the way they worked. Several important steps were required, however.

The first step was to begin with a good image of the mosaic to use as a base map. The image had to be of sufficient resolution for the conservators to see each small, 30 × 30-millimeter-square tessera. This step required specific expertise, so the conservation team hired a Czech company to photograph, accurately measure, and process the images to be used for the base map. Each panel of the mosaic was photographed in its entirety with a medium format (13 × 18 centimeter) Carl Zeiss Jena UMK 10/1318 camera with a Lamegon 8/100 lens using Kodak Ektachrome E100s color film, speed 100ASA. The film was then developed and scanned with a photogrammetric Zeiss/Intergraph TD scanner.

High resolution is only one aspect of creating a good base map; the images also have to be distortion free. Distortion is caused by the curvature of the lens, the film, and the position of the camera in relationship to the subject. With accurate measurements of the mosaic and knowledge of the camera and lens geometry, any distortion can be removed through computer processing.

In the second step, the sharp corners of ten individual tesserae on each panel were selected as control points. Then, their three-dimensional coordinates were measured with a Wild T2000/ Distomat DI1600 total station. Using the target measurements and the computer program PhoTopoL, the digital images were then rectified, or transformed, and correlated to fit actual dimensions of the mosaic. The removal of distortion and the placement of the images to exact scale were crucial, as each of the three panels was photographed separately during different phases of the work. This allowed images taken before, during, and after conservation of each panel to align exactly.

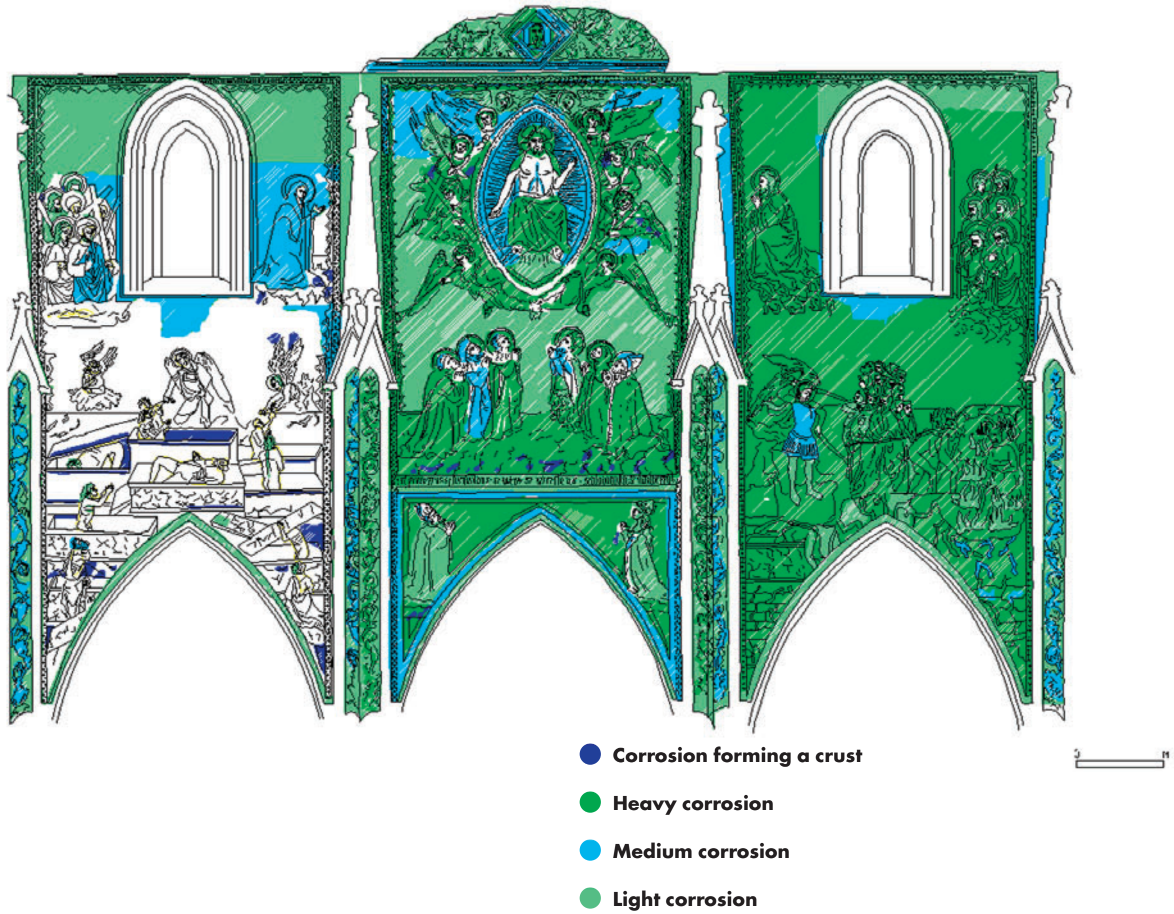
Conservators at St. Vitus Cathedral inspecting the mosaic, recording conditions on transparencies overlaid on rectified photographs of the facade. Photo: Dusan Stulik.

In the third step, the distortion-free images and measurements were imported into AutoCAD, a computer drafting program, and sent to the conservators. Using this program, a grid was then drawn every 20 centimeters over each image, both vertically and horizontally. This, along with a naming standard, created a coordinate system that allowed the team to reference specific sections of the mosaic. For example, Christ passing judgment is located at LJCBC B4. This refers to the *Last Judgment* (LJ), center panel (C), before conservation (BC), column B, row 4. Four rows by four columns were then printed at a scale of 1:4 on A4 heavyweight paper. A4 transparencies were also printed with a corresponding grid in order to align properly with the image of the mosaic. This proved to be a good size, as it was manageable on a clipboard yet still provided an acceptable level of detail. By using the base map image and transparency overlay, conservators could work on the scaffolding to manually record important features.

Information collected by conservators on the transparencies was scanned and imported back into the computer model. Prior to collecting information on the transparencies, it was found that certain colors–green, yellow, and other light colors–were not optimal for scanning. Therefore red, dark blue, black, brown, magenta, and orange were chosen for use. It was also important that only new markers were used. A condition legend was created that corresponded to each color. Red referred to cracks, magenta to traces of original gold, and blue to missing tesserae. In addition, extra transparencies were made available if the conservator made a mistake; no corrections were possible given that the transparency was scanned. All of these issues were carefully explained to the conservators, who were required to change their usual methods.

After the transparencies were scanned as bitmaps, they were converted into a form that could be included in a computer drawing program. Bitmaps (or raster graphics) are how computers and programs such as Adobe Photoshop record and display graphic images. The computer image created from the scan of the transparency is composed of millions of individual points (or pixels) of color. The number of points determines the resolution of an image. In this form, the information is not easy to calculate, combine, or separate into distinct divisions or layers; it is also of limited use at a large size. The individual points in a bitmap image can be seen if printed too large, resulting in uneven lines. The scanned data had to be converted into a different form—a vector graphic image. Vector graphics represent an image through numbers or mathematical models, and in this form it could be combined and manipulated more easily. Cracks could be measured and areas calculated because the graphics are based on numbers, not just on individual points. Vector graphics could also be printed at any size without a loss in resolution. A computer program, Adobe Streamline, was used to perform this conversion. Once complete, the data from each separate transparency were digitally reassembled on top of the image of the mosaic.

Scanned transparency of the mosaic, with graphic recording of corrosion levels. Drawing: Rand Eppich.



Rectified images of the facade, showing its state before conservation (*left*), after treatment (*center*), and after gilding (*right*). Images: Jaroslav Zastoupil.

This simple method allowed a team of five conservators to manually record the condition of each panel in approximately two weeks. It only slightly altered the way they traditionally work, requiring very little training in the use of computer graphics. One junior member of the team was trained in scanning the transparency images, converting them from bitmap to a vector form and then assembling them back into the AutoCAD file. This same member was also responsible for all data management on site and additional work that was accomplished several weeks later. Once the documentation was finished, corrections and additions were made and the data printed at various sizes for further use in the project. The observations of the conservators aided in forming the subsequent treatment plans and also served as a benchmark for future work on the mosaic. At the end of the project, the data were archived in both print and digital form in Prague and Los Angeles.

Alternative tools, such as the direct use of laptop computers, were considered, but this required too much training and may have been a distraction while working on the scaffolding. Computers that allow the operator to draw directly on screen were also considered, but at the time of this project the technology had not progressed sufficiently. This methodology is still viable for projects without sufficient funds to purchase computers. Minimal training was required for the expert conservators but some training in scanning and AutoCAD was needed for the junior member.

An Answer

Conservators recorded the condition of the mosaic in order to understand and note issues that led to a conservation strategy. The techniques used in this example allowed them to conduct their evaluation without significantly changing their methodology.

The information collected, once converted to digital form, allowed conservators to view various conditions in new and different ways. Cracks and areas of loss were easily measured, as were patterns of corrosion relating to the different types of tesserae. The mosaic and the condition record were studied in detail away from the site, in multiple locations, which facilitated communication among the experts. Prints were made at various scales for use on the scaffolding and in presentations to both the public and professionals. Historic photographs were also scanned and included with the condition record. This method provided a tool that was more flexible and useful than if the documentation had not been digital. It also provided a complete visual description of the mosaic and serves as a record of recent interventions.

After the record was complete, the final phases of the project were carried out. A suitable method for removing the crust was tested and used. The mosaic was cleaned using compressed air and microscopic glass particles that were harder than the crust but softer than the tesserae. After cleaning, the surface was prepared with a solvent to remove any remaining residue. Each tessera was then treated with a complex protective coating that consisted of several layers. The outer layer is sacrificial and needs to be replaced every five years, whereas the inner layer is more durable and expected to last at least twenty-five years. This coating will shield the mosaic from the elements while allowing it to remain visible. The mosaic is inspected annually and photographed systematically in detail to determine if the coating is still functioning. Plans are in place to photograph and measure the entire mosaic every five years.

Rand Eppich is a licensed architect in California who established and is currently managing the Getty Conservation Institute's Digital Recording Lab for architectural documentation and site analysis. He has been elected to membership to CIPA (International Committee for Architectural Photogrammetry) and has taught courses on architectural conservation and documentation at ICCROM and at the University of California, Los Angeles.

Dr. Dusan Stulik is a senior scientist for the Getty Conservation Institute, specializing in photograph conservation. His current research involves development of scientific methodology for identification of different photographic processes and process variants.

Jaroslav Zastoupil, a measured building surveyor and photogrammetrist, was born in Varnsdorf, Czech Republic. He studied at Czech Technical University, Prague, in the Department of Mapping and Cartography. In 1997, he established Zastoupil a Král Land Surveyors and has worked on such projects of significance as the Karlstejn Castle, Chateau Veltrusy, and the Pilgrimage Church of St. John of Nepomuk, on Zelená Hora.

Building Survey

Christian Ouimet

Fort Henry is strategically located in Kingston, Ontario, Canada, at the confluence of the St. Lawrence River and the Rideau Canal, at the eastern end of Lake Ontario. Time and climate have taken their toll on this immense masonry complex, which was built by the British in the 1830s to defend their interests in Upper Canada. In 2000, the decision was made to reevaluate the condition of the fort, and a comprehensive multiyear conservation project was initiated. Extant recording was a critical component of the conservation work.

How can data gathered from a variety of techniques and tools be combined into one shared format to aid in the long-term assessment and conservation of this massive complex?

This illustrated example was completed with the assistance of Bryan Mercer, marketing officer, and Ron Ridley, curator, Fort Henry National Historic Site of Canada, St. Lawrence Parks Commission, Ministry of Tourism. They provided images and details of the ongoing work at Fort Henry, even as the conservation work on the East Branch ditch tower was under way.

The East Branch ditch tower of Fort Henry, overlooking Lake Ontario and the mouth of the St. Lawrence River. Photo: Christian Ouimet © Heritage Conservation Directorate, Public Works and Government Services Canada.

Fort Henry, Canada

Fort Henry is located in Kingston, where the St. Lawrence River leaves Lake Ontario at the start of the Rideau Canal system. It is situated at the easternmost point of the Great Lakes, the major transshipment route for all points west during the eighteenth and nineteenth centuries. The Great Lakes and St. Lawrence River also formed the border between British-controlled Canada and the United States. The fortification consists of the main redoubt and advanced battery, built between 1832 and 1837 to replace an existing fortification from the War of 1812. Fort Henry was designed to protect the Canadian border, its waterways, the Rideau Canal, and the adjacent naval dockyards. Enlarged in the 1840s with the construction of commissariat stores and two outlying towers, it soon became one of the largest, costliest, and most complex fortifications in Canada. The fort represented a significant commitment by the British to protect Canada and was garrisoned until 1870; it was then used by the new Canadian army until 1891.

After 1891, Fort Henry stood abandoned until 1923, when it was declared a National Historic Site. It was first restored between 1936 and 1938. During the First and Second World Wars, it served as an internment and prisoner-of-war camp. The government of Ontario began to operate Fort Henry as a museum and heritage attraction in 1938, under an agreement with the Department of National Defence (DND). In 1999, the federal government transferred administrative responsibility for the site from DND to Parks Canada. The St. Lawrence Parks Commission, an agency of the province, continues to operate Fort Henry. Every summer the site is brought to life by telling the story of the fort through the internationally renowned Fort Henry Guard, guided tours, museum displays, and special events. The complex consists of many individual structures: the main fortification, or redoubt, the commissariat stores, reverse fire chambers, advanced battery, stockade buildings, and the two outlying (branch) ditch towers, so called because they are set above deep trenches.

Canada's cold, wet winters have had their impact on these buildings. The wood rafters of the commissariat stores decayed as a result of a leaky roof. The retaining walls of the fort's entrance ramp deteriorated and required structural stabilization. The limestone blocks that make up the redoubt were fractured and spalling, and the mortar had deteriorated significantly. In the interest of safety, some areas were initially stabilized, but due to the fort's size, complexity, and condition, Parks Canada and the St. Lawrence Parks Commission developed an ambitious long-term conservation plan.

Recording of the fort was initiated to support the conservation efforts and to identify areas requiring immediate attention. Before beginning, it was important to get input from stone conservators, engineers, architects, and building contractors. Stone conservators required surface detail to see the condition of masonry and mortar; architects and engineers needed a comprehensive site plan to coordinate activities; and contractors needed measurements to prepare estimates.

At the outset, questions were raised: Which components of the buildings are to be recorded? What types of drawings are needed: floor plans, sections, or elevation drawings of the walls? What levels of detail and precision are required? Conservation specialists and building contractors recognized the importance of having current and accurate information with which to work.

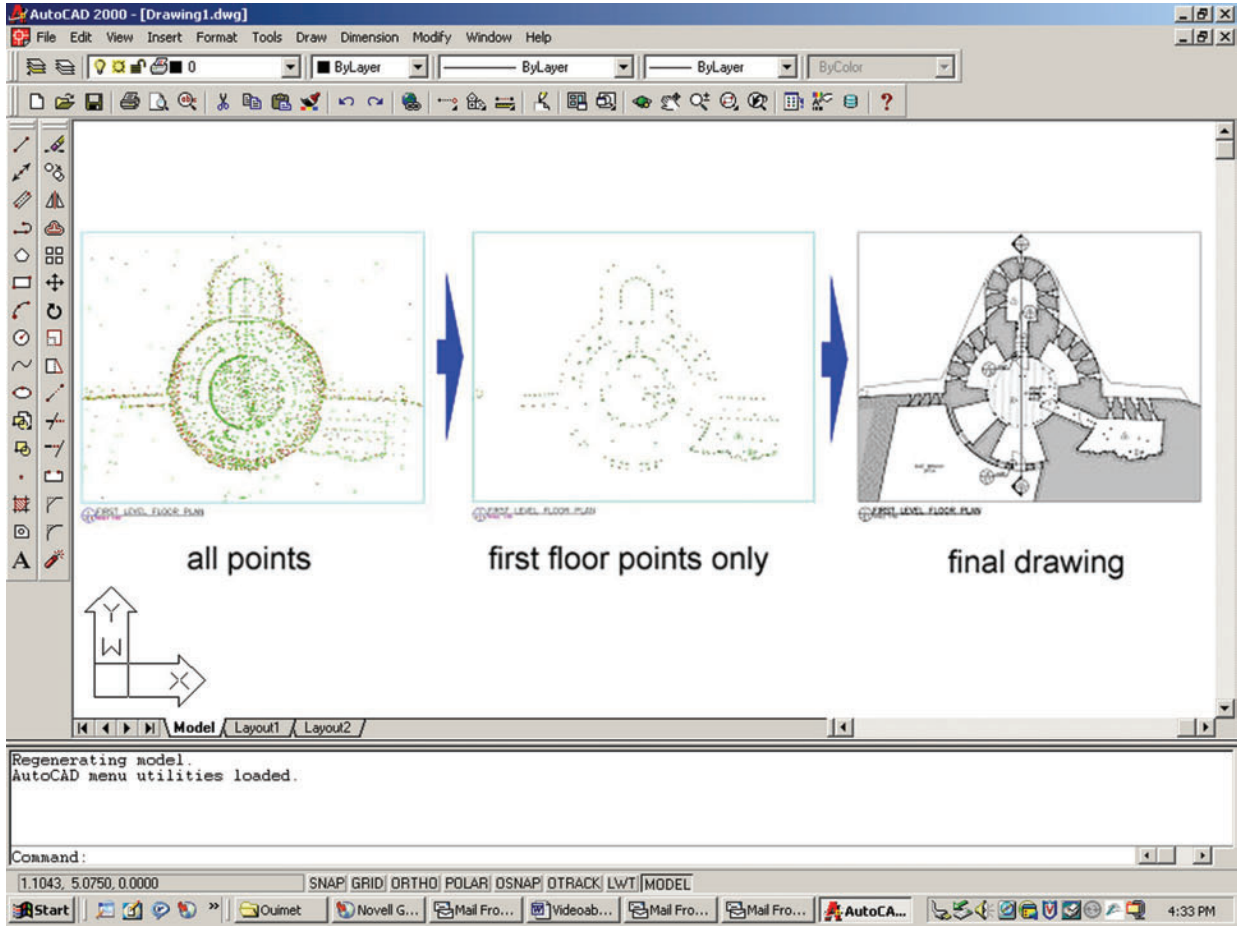
Fort Henry is strategically located on the trading routes between Montreal, Ottawa, and all points west. In the background, the Rideau Canal leads to Ottawa; in the foreground, the St. Lawrence River leads to Montreal. Photo: © Fort Henry National Historic Site of Canada–Archives.

Fractures and spalling of the limestone blocks in an archway of the redoubt. The mortar joints had also deteriorated significantly. Photo: © Fort Henry National Historic Site of Canada–Archives.

Computer-Aided Design and Drafting

Once the aforementioned questions were answered, the next step was to select the appropriate tools and methods to obtain the information needed by the specialists. Although time and cost were important factors, the primary consideration was to fulfill the needs of the conservation specialists. Rectified photography was chosen for the exterior elevations, hand recording with a tape measure for the interior rooms, and survey instruments (including a total station theodolite) to provide overall detailed measurements of the site and exterior curved surfaces. The rectified photography of the walls provided the necessary level of surface detail for the stone conservators to chart cracks and spalling damage and to identify ashlar blocks in need of repair or replacement. For the engineers and architects, the survey plan of the entire site proved indispensable in planning and scheduling the long-term interventions. For budgeting, the building contractors used the measurements to calculate the amount of materials required. Creating the documents that these specialists needed required software that could combine information from multiple sources.

Computer-Aided Design and Drafting (CAD) is software essential to conservation specialists. It enables measurements, data, and images from multiple tools and methods to be combined. CAD is flexible enough to allow the user to produce quick, basic sketches, as well as drawings of great precision and detail. Serving as the common platform for printing and sharing data among specialists at different stages of conservation, images can be imported and data added manually or input directly from survey instruments. Data can be displayed in different ways, including two-dimensional orthographic projections or



Screenshot of the CAD drawing of the West Branch ditch tower, showing the initial data points recorded with the total station (*left*), the later edits (*center*), and the final section drawing (*right*). Drawing: Christian Ouimet © Heritage Conservation Directorate, Public Works and Government Services Canada.

three-dimensional isometric, or perspective, views. Information can be divided using multiple layers, or views, which can then be recombined in various ways. For example, a single site plan can serve both an engineer with a drainage layer and an architect with a visitor path layer.

Autodesk's AutoCAD, a widely used brand of CAD software, was chosen for this project. The first source of data entered into AutoCAD was the total station theodolite survey of the entire Fort Henry complex. This survey established a local coordinate system that provided control, or reference, for all subsequent measurements by other methods. This single coordinate system permitted the combination of information such as building location, wall thickness, wall condition, height, and elevation. It also allowed the combination of data collected over time, an important consideration in a multiyear project.

Once this coordinate system had been established, the strength of CAD became apparent in the assessment of the redoubt's stone wall. The software allowed the team to directly import images of the exterior elevations. The images were placed and scaled (rectified) using measurements obtained from survey targets placed on the stone wall surface. Stones and mortar joints were traced from the images and placed on assigned layers. Stone conservators noted on the drawings where mortar and stones had deteriorated and where replacement or repair was needed.

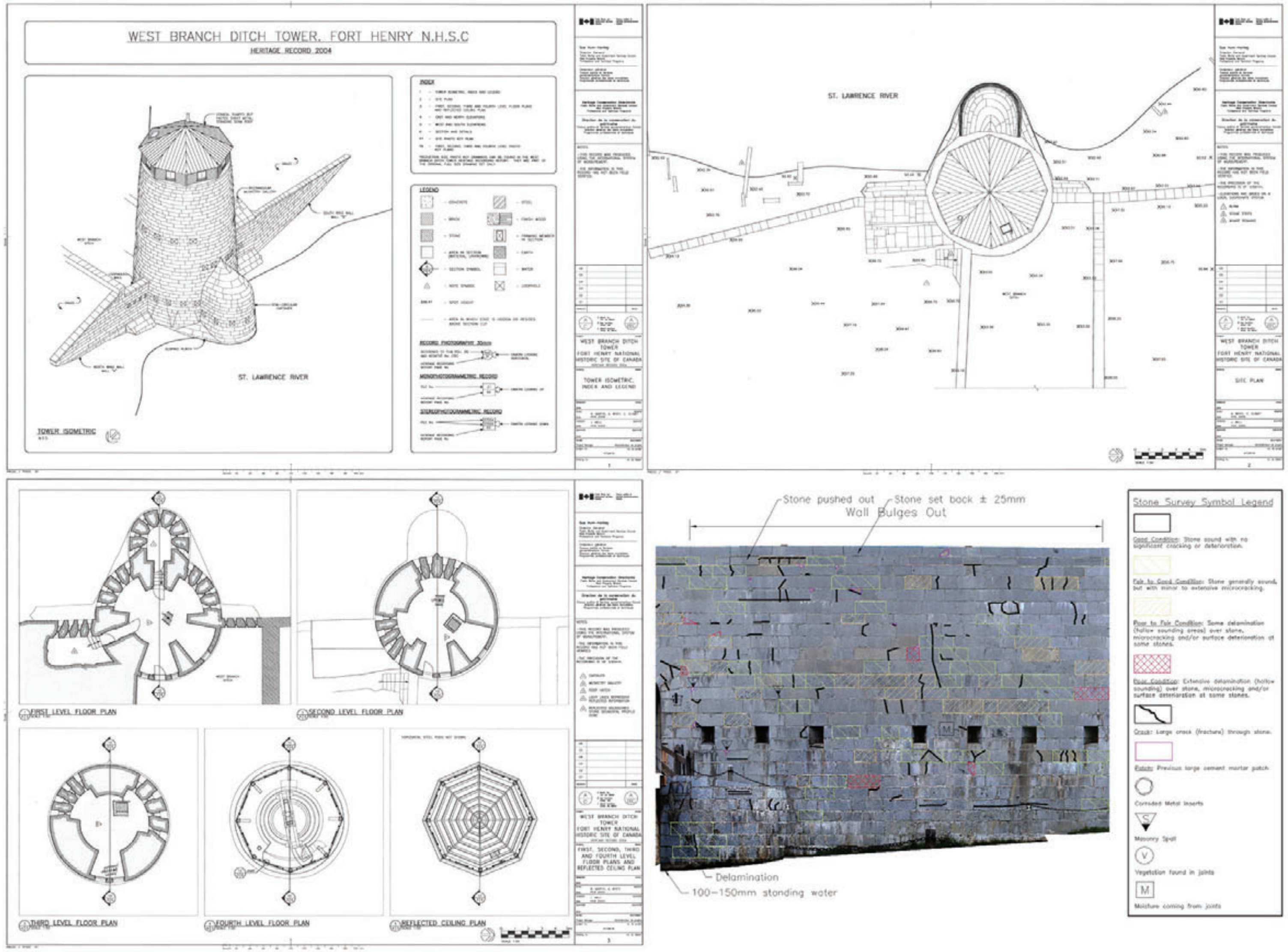
Survey with the total station theodolite was also the primary method for collecting the measurements of the curved exterior surfaces of the branch ditch towers. Measurements from each of the four floors, window openings, roof outlines, and other features were placed onto separate layers. This gave the team greater flexibility in producing the drawings, including a three-dimensional model of the towers' exteriors.

The interior of the towers and the timber-frame roof structures of the commissariat stores were measured by hand due to the small size of the spaces. These interior measurements were related to the overall coordinate system via window openings so that once the measurements were entered, they would align with those taken from the exterior. The CAD software made possible the combination of both sets of measurements obtained from different methods. Cross sections through the tower walls were created using these measurements.

Naming conventions based on existing historical names, locations, and features were applied to the data collected and to the CAD layers, drawings, and directories. Using a naming convention that all specialists could share was essential for multidisciplinary communication. It also allowed the CAD operators to create and draw various CAD files simultaneously.

The final drawings created in AutoCAD included the overall plan of the fort, rectified images of the walls, isometric views, sections, elevations, and plans of the towers; a condition assessment of the stone and mortar was also incorporated. The site work for the overall plan and redoubt involved six heritage recording professionals and took two weeks, followed by two weeks of office work by four CAD operators. Site work for the towers took two weeks during the summer and two days in winter with two recorders. In winter, the areas of the towers that faced the water were recorded from the ice surface, which allowed the recording team to collect data not accessible earlier. Office work in AutoCAD for the towers took approximately two months with two CAD operators.

In subsequent phases of the project, engineers and architects used the CAD drawings for the development of the final conservation plan and the preparation of tender documents for bidding by building contractors. Making the drawings available to the latter increased their understanding of the materials needed for the conservation work and greatly assisted with their cost estimates. The project manager attested to the significant savings in both time and cost for the work done. In fact, the contractor selected to perform the conservation work used the drawings as a primary tool in guiding his workers.



Elevation and section drawings of the West Branch ditch tower. Included is the condition survey of the facade masonry and mortar. Drawings: Christian Ouimet © Heritage Conservation Directorate, Public Works and Government Services Canada.

An Answer

In fall 2002, the rampway leading into the fort, along with the fort's retaining walls, was stabilized and reinforced, and any damaged stone was replaced. Treated steel anchors were inserted through the walls to provide additional structural stability, and the walls were waterproofed from behind. This was followed in 2003–4 with the repair of the timber structures of the commissariat buildings and the reroofing of the buildings with historically appropriate materials. A three-year project commenced in 2004 to waterproof, repair, and stabilize the redoubt, and in fall 2006, conservation work was begun on the East Branch ditch tower to restore the roof and repair the stone walls. This work continues in 2007 on the West Branch ditch tower. Other conservation projects currently in the planning and implementation stages include the repair and repointing of the advanced battery and the north wall of the redoubt. Each intervention reflects a commitment to respecting the established heritage character of the site.

Workers removing deteriorated mortar from the East Branch ditch tower for repointing. Photo: © Fort Henry National Historic Site of Canada–Archives.

The scaffolded East Branch ditch tower during the restoration project. Photo: © Fort Henry National Historic Site of Canada–Archives.

CAD software has dramatically changed the way drawings have been produced over the past twenty years. Drawings can now be easily manipulated, changed, copied, transmitted, and printed in a variety of ways. Along with improved production efficiency, drawings produced with CAD have a more consistent look. Most important, however, CAD provides a means by which drawings from numerous sources can be combined. This combination of sources increases the value of the original data and allows engineers, architects, conservators, and other specialists to gain a better understanding of a structure or site. It also provides greater flexibility for the sharing of information. The CAD work undertaken in support of the conservation efforts at Fort Henry not only provides a record for posterity but also continues to assist during the entire conservation process.

Editor's note: In 2007, the Rideau Canal, Fort Henry, and the Kingston fortifications were inscribed on the UNESCO World Heritage List.

Christian Ouimet is an architectural conservation technologist with the Heritage Recording Unit of the Heritage Conservation Directorate, where he is involved in the documentation and monitoring of monuments, buildings, and sites by means of various documentation tools. He has worked on various projects, from large industrial sites such as the Britannia Mines Concentrator Mill Complex, near Squamish, British Columbia, to topographical battlefield terrain at the Canadian First World War Memorials, in Europe. He has also recorded entire towns, including Old Town Lunenburg, Nova Scotia, a World Heritage Site.

Inspecting Sites

Kevin L. Jones

Rising above the lush landscape of New Zealand, *pā* are Maori fortified settlements built on natural earth formations. Beginning in the mid-sixteenth century, they were built with soil ramparts, terraces, and agricultural areas and usually surrounded by deep defensive ditches. Important archaeological sites, pā embody the *mana,* or spirit, of ancestral Maori chiefs. Over the past century, urban development, farming, overgrazing, and erosion have endangered many of these sites.

With more than 6,600 of these fragile pā located in mostly remote areas, how can their condition be recorded, monitored, and assessed, and conservation interventions planned?

This illustrated example was completed with the assistance of Stephen Lamb, senior resource planner, Environment Bay of Plenty, New Zealand. The Papamoa Hills Regional Park Management Plan (November 2006) was an invaluable resource for understanding the history, issues, and conservation approach of Te Uepu and Environment Bay of Plenty.

The terraces and transverse defensive ditch of the southern platform of Karangaumu pā (pre-European Maori fortification), Papamoa Hills, near Tauranga, North Island, New Zealand. Photo: © Environment Bay of Plenty, New Zealand.

Karangaumu pā, New Zealand

The Papamoa Hills at the Bay of Plenty, near Tauranga on the North Island of New Zealand, are historically and culturally significant, as they are believed to be one of the first landing sites of the Maori in the late 1300s. Nine fortified pā were built at Karangaumu, on top of these hills. These pā were of strategic importance to the Maori because of their commanding views of the ocean, islands, and low-lying coastal plains. Built primarily as a stronghold against attack, they were also used as living and storage places, as well as centers for learning, crafts, and horticulture. The pā on these hills are unique in that there are few examples of Maori sites so numerous and well preserved, and in so small an area.

However, the hills are under threat from surrounding development, nonnative plant species, and growing tourism. The soft soil is also vulnerable to erosion from water, wind, and grazing. Livestock grazing maintains the open grassland environment and prevents nonnative trees from damaging the site, but at the same time it causes erosion from the concentration of sheep tracks near gates, watering troughs, and roads. Although existing farm roads are a common cause of damage to pā, they do provide a route through steep ground and restrict livestock to places already damaged.

It is not known how the Papamoa Hills passed from Maori ownership to the British Crown. However, in the 1890s, John McNaughton, an early settler, purchased the hills that include most of the site of the present-day park. Used for more than a hundred years as a sheep and cattle ranch, the McNaughton family fortunately recognized the historical and cultural value of the land and eventually endeavored to protect it.

In 2003, the family sold the land to three local authorities (two local councils and one regional council). The land is now owned solely by the regional council, Environment Bay of Plenty, and is managed as a regional park on behalf of the Bay of Plenty community. Joint management with local iwi/hapu peoples ensures that the cultural aspects of land use are incorporated into operational decisions. Papamoa Hills Regional Park is known also as Te Rae o Papamoa, the name for one of the prominent pā. The name means "the forehead of Papamoa"; Papamoa was an ancestor of the first Maori to settle in the area.

To provide guidance in how this important site should be used, both a management plan and a heritage conservation plan were needed. The management plan focuses on how the land is used, while the heritage conservation plan specifically addresses how the heritage and archaeological features are to be protected. These plans were written in conjunction with Te Uepu, a caucus of the four iwi/hapu groups created to advise on Maori culture and tradition. A record of the 135-hectare site was required to support the plan and to fully understand the physical characteristics and factors affecting its condition. This record was also needed for monitoring, the process of recording conditions at intervals to determine the nature and rate of change and whether intervention is needed. In addition, New Zealand law, through the Resource Management Act, requires local and regional governments to monitor environmental factors.

Prominent lateral defensive ditch and terracing on Karangaumu pā. Photo: Kevin L. Jones © New Zealand Department of Conservation.

Aerial Photography

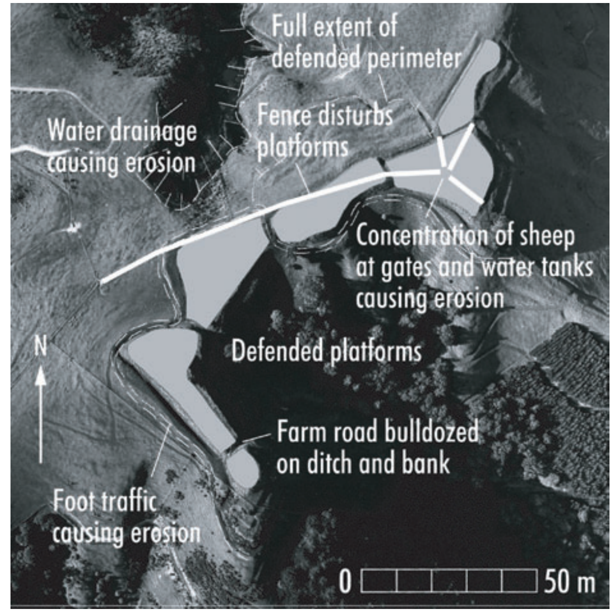
Aerial photography provides an efficient and effective means of quickly documenting the condition of a large site or a number of sites. They document many relevant matters relating to the physical state of a site and can also show disturbances such as urban sprawl, farming activities, looting, and forest encroachment. In addition, aerial photographs, if sufficiently detailed, can be a substitute for conventional mapping and for monitoring purposes.

There are two general sources for obtaining aerial photography: archival research and commissioning flights. Archival research is a cost-effective means of acquiring images of a site taken for reasons such as road engineering and national topographic mapping programs. Photographs taken for this purpose often are of very high quality and at an original scale ranging between 1:10,000 and 1:50,000. They also have great value simply because they may show sites before the sites are modified.

Commissioning flights is the second source for obtaining aerial images. These images can be vertical (straight down) or oblique (taken at an angle). Professional companies usually take vertical images by using expensive, extra-large-format film or digital cameras mounted in the belly of a small airplane. This conventional aerial photography has become somewhat expensive to commission but provides excellent resolution and up-to-date data.

A less expensive option is oblique (or near vertical) photography. Oblique images are taken during a flight by the copilot or passenger. These photographs can be taken with either small-format (35mm) or medium-format (120mm or 6 × 6 centimeter) film cameras or a high-resolution (10 megapixel) digital single lens reflex (SLR) camera. Oblique images have many advantages for mapping and monitoring areas of the size of most archaeological sites or building complexes. Although more difficult to map or scale because they are not vertical, they are nevertheless sufficient in that they reveal many details and conditions of earthwork archaeological sites and can cover areas up to 600 meters across. They are particularly effective in monitoring sites over time and can cover numerous sites (fifty or more) in the course of one well-planned flight lasting two to three hours. The cost per site monitored is lower than visiting remote sites as part of a vehicle-based ground crew, where access may take as long as two to three hours, and the number of sites visited per day would seldom be more than ten.

Because the Papamoa Hills extend over a large area that is difficult to access, large-format vertical aerial film photography was commissioned to record the entire site, earthworks, and archaeological features of the park, including some of the surrounding areas. The significance of the site required an image that could be accurately measured and then used as a base map for planning interventions. The final images were created from scanned aerial contact prints shot with a Leica RC30 metric camera system fitted with forward motion compensation (FMC), during a series of flights in the summer of 2003 and 2004 by Fugro Airborne Surveys, a private aerial photography company. These images were then digitally orthorectified, or aligned, to remove irregularities and distortions in scale caused by the camera lens, film, plane, or terrain. They were also georeferenced with real-world coordinates obtained from existing maps and ground control measured points. This allowed for the seamless addition of multiple



Vertical aerial photograph of Karangaumu pā, on the Papamoa Hills. Photo: Kevin L. Jones © New Zealand Department of Conservation.

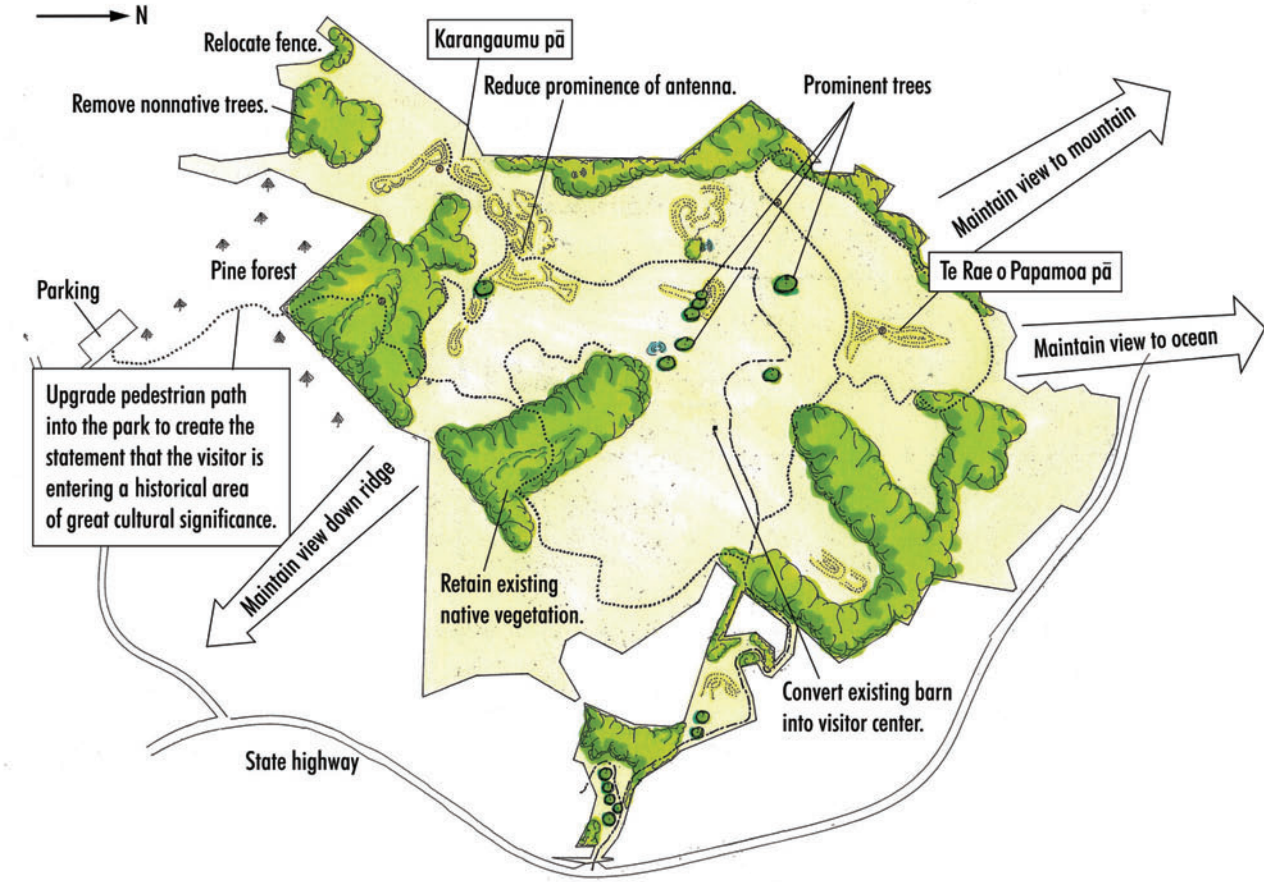
The author preparing to take oblique aerial photographs of pā on the North Island of New Zealand. Photo: Kevin L. Jones © New Zealand Department of Conservation.

distortion-free images that could be accurately measured and related to surrounding areas. All photos were then quality checked for color, contrast, and accuracy.

Technologies that compete with aerial photography include ground plans drawn in conventional ways, such as with survey instruments (total stations) or Global Positioning System (GPS). Aerial surveys can also use radiation emission sources such as laser scanners (LIDAR, light detection and ranging). Where a site is obscured by vegetation, conventional ground plans are essential as aerial photographs may reveal little. Although these technologies provide highly detailed topographic contour plans and line drawings, they still lack the information obtained from an aerial photograph. Often these technologies must be used in combination. Recently, low-cost digital satellite imagery (Digital Globe) has begun to compete in convenience with aerial photography; however, images obtained from airplanes are still much higher resolution (approximately several centimeters per pixel) than those obtained by the most advanced commercial satellite (approximately 1 meter per pixel).

Conservation planning for archaeological sites needs cost-effective and flexible tools for recording conditions. Aerial photography is just such a tool: large sites can be quickly recorded, revealing many features and conditions not readily seen from the ground. In addition, aerial photography can also assist in economically monitoring numerous remote sites. If taken periodically, such images can show deterioration and alert managers to impending losses. Aerial imagery can also indicate the extent of subsurface sites or features, such as the slight depressions, or terraces, of earthwork fortifications.

Orthophotographic aerial photography of the entire Papamoa Hills Regional Park. Photo: Fugro Airborne Surveys © Environment Bay of Plenty, New Zealand.



Landscape concept design for Papamoa Hills Regional Park. Drawing: Landscape Company Limited © Environment Bay of Plenty, New Zealand.

The interpretation of the aerial imagery of the Papamoa Hills guided the conservation recommendations for the management plan of the park. The aerial images of Karangaumu pā, to the west of the site, revealed several conservation issues: a farm road had been bulldozed through the pā from the southeast along the lateral ditch and bank defenses; gates, water tanks, and fences on the northern platform concentrated grazing sheep, leading to erosion; gullies on the northwest side have slowly eroded the slope; and minor erosion has resulted from people walking on the main platform down to the central transverse ditch area.

An Answer

In November 2006, a draft of the Papamoa Hills Regional Park Management Plan was completed using aerial photographs to locate features and describe threats. Aerial photographs also served as the base map for proposed conservation of the archaeological sites. To preserve the archaeological remains and the landscape of the park, it was recommended that sheep grazing be carefully managed in order to maintain good grass cover, and that farm-fencing patterns be reconsidered. Erosion from animal behavior can be corrected by a thorough review of the water supply areas and shelters in the available paddocks and the creation of less damaging alternatives. In some cases, the simple removal of an unnecessary fence would be adequate, allowing access to water and improved shelter without damaging the pā. Placement of visitor facilities, access, and parking was planned using the aerial images. The photographs were also used to note important views, prominent trees, and nonnative species for the landscape design.

Overall, aerial photography proved to be a valuable tool for the Papamoa Hills Regional Park Management Plan. The methods demonstrated in this example have potentially wide applicability in other countries with surface-visible archaeological sites and suitable ground conditions (grass, desert, planes), and where military authorities will allow widespread aerial photography. Archived historical aerial photographs may allow for longer-term monitoring.

Kevin L. Jones is an archaeologist in the Research, Development and Improvement Division of the New Zealand Department of Conservation. He is the author of a book on New Zealand aerial archaeology and is writing a field guide to New Zealand archaeology for the Penguin Group. He has conducted extensive field research and has been involved with World Heritage policy in the Pacific.