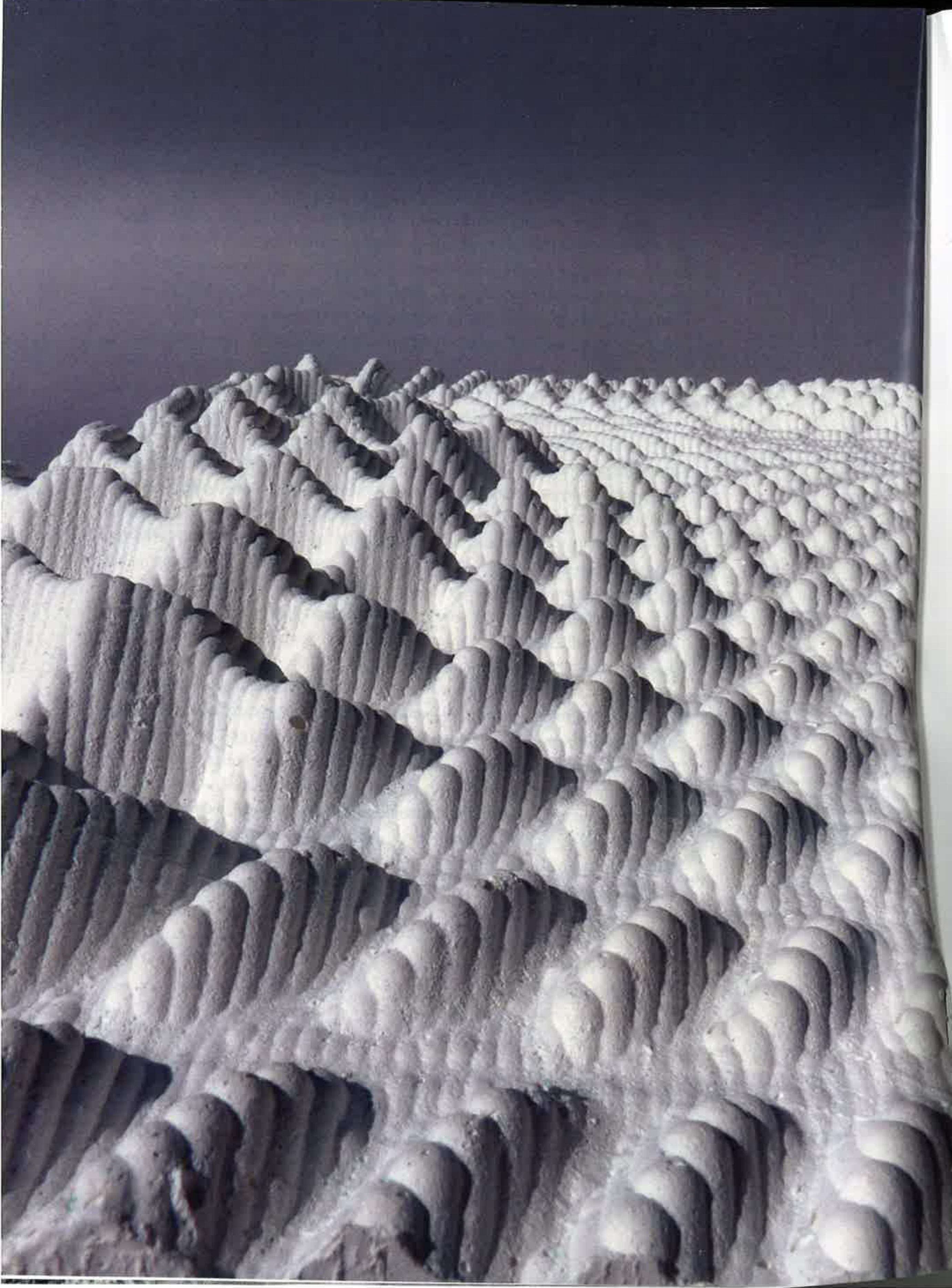


1.1
Knob land form, Fall Foundational Studio 2013, University of Virginia.

1 Topographic surface

In this chapter we explore the potential of digital technologies for designing topography. We begin with a discussion of design explorations and theoretical writing emerging in architecture during the late twentieth century. At first glance, this might seem odd for a chapter focusing on topography. However, as will soon become apparent, the transformative moments in architecture in the 1990s, form an important foundation for understanding concepts and techniques now being adopted in landscape architecture. Throughout this chapter these new cross-disciplinary concepts will be explained and contextualised within landscape architecture. This discussion should also be considered in conjunction with the time line of ideas and technological developments featured in the Introduction.

The work of Ivan Sutherland was a major catalyst for what has become known as computer aided design (CAD). In 1963, Sutherland developed the Sketchpad computer program (also described as Robot Draftsmen) as part of his Ph.D. studies at the Massachusetts Institute of Technology (MIT). His work highlighted the potential of computer graphics to be used for both technical and design purposes, while also proposing a unique method of human–computer interaction. Importantly, Sutherland's work can be considered the first example of parametric software, a concept which will be introduced in more detail further in this chapter.[1]

Following Sutherland's influential lead, developments in CAD evolved in two key directions; first, in the ambition to develop a computer graphics system for interactive drawing, and, second, in the exploration of the computer's potential to inform methods of design more directly. In the first case, computer graphic systems were sufficiently developed to be released into industry by the early 1980s – ArchiCAD became available in 1982 (considered the first CAD product for use on a personal computer, the Apple Macintosh), followed by AutoCAD in the same year.

These two systems were adopted as industry standards for 2D and 3D drafting and technical drawings across architecture, engineering and landscape architecture throughout the 1980s and early 1990s. However the application of computer graphic systems by most designers remained limited to the translation of established representational conventions such as plans, sections and elevations into digital files; essentially drawing through a digital means.

In contrast to simply replicating the pen with the mouse, the second approach sought to explore the computer's ability to influence design generation. This work focused initially on the concept of object-based architectural grammars and spatial allocation techniques for rationalising approaches to design, popular during the 1970s and 1980s. This emphasis on the 'computability of design' in many ways mirrored the rationale approaches proposed by GIS which was unfolding in the same period. The work of Architecture Machine Group established in 1968 at MIT, which evolved into the Media Laboratory, was significant. Director William J. Mitchell produced two seminal texts *Computer-Aided Architectural Design* in 1977 and *The Logic of Architecture: Design, Computation and Cognition* in 1990. Building on the influence of geometry in determining architectural form, Mitchell conceived of architecture as a series of formal grammars that could be modified through the application of grammatical rules.

While these early object-driven design explorations had limited application to landscape architecture, this was to alter in the 1990s when architects became interested in the potential of non-Euclidean geometries, which had first emerged in mathematics during the early nineteenth century. During this period, mathematicians developed geometric alternatives to Greek mathematician Euclid's planar and solid geometries described in his treatise *Elements*. Euclid's fifth postulate proposed 'that for any given infinite line and point off that line, there is one and only one line through that point that is parallel'.[2] The publication of elliptical (or Riemannian) geometry and hyperbolic geometry challenged this postulate, and it was the possibilities of these new geometries as 3D surfaces that captivated the imagination of architects towards the end of the twentieth century.

This interest in the new potential of continuous surface combined with the emergence of a theoretical terrain aimed at addressing the tensions inherent between the two competing ideologies of Postmodernism; that of Contextualism and Deconstructivism, inspired a transformative move towards what could be considered an architectural 'digital design practice'. The writing of French philosopher Gilles Deleuze was particularly influential. His essay 'The Fold: Leibniz and the Baroque', which was translated into English for the first time in 1992, provoked spatial possibilities for envisaging concepts of complexity and contradiction, both pivotal Postmodern framings featured prominently in the work of the Deconstructionist-inspired architects.

Peter Eisenman was one of the first to explore Deleuze's essay 'The Fold' in relationship to architecture. He was pivotal in articulating 'a new category of objects defined not by what they are, but by the way they change and by the laws that describe their continuous variation'.[3] For Eisenman, the notion of the fold offered an exciting alternative to gridded space of the Cartesian order, challenging the binary distinctions of the interior–exterior and the figure–ground. The exploration of these ideas was continued by Greg Lynn who, informed by Deleuze's definition of smoothness 'as continuous variation', proposed new ways for conceptualising spatial complexities. His essay 'Folding Architecture', published as the keynote essay of a special themed issue of *Architectural Design* (*AD*) in 1993 is considered a turning point in the history of Deconstructivism in relationship to design. Lynn defined 'smooth transformation' as 'the intensive integration of differences within a continuous yet heterogeneous system' and identified the concept's value in resolving the tensions inherent between the pursuit of Contextualism, order and composition versus Deconstructivism's alternative focus on opposition, fragmentation and disjunction.[4] Significantly, smoothness could be understood as a 'mathematical function derived from standard differential of calculus'.[5]

Technological developments in hardware and software emerging in parallel provided the opportunity for architects to explore these theoretical ideas through space and form. The application of spline (understood most simply as a line that describes a curve) modellers in architecture sourced from the aviation and automobile industry was one of the most influential advancements, offering designers faster and more intuitive means for exploring calculus-based forms. These technological advancements fundamentally altered the designer's relationship to the design process, blurring the boundary between software design and the designer through a series of new generational techniques such as parametric modelling, simulating and scripting.[6]

This moment of late twentieth-century architectural design history exemplifies the intrinsic relationship between technological opportunity and theoretical ambition, with both necessary for innovative outcome. The writings of Eisenman, Lynn, Stan Allen and Bernard Cache, together with design explorations by firms such as Foreign Office Architects and Frank Gehry offered compelling demonstrations of the potential of this theoretical terrain to inspire novel architectural form. This capacity was made possible through the innovative software and hardware developments, emerging from outside the architecture professions. Mario Carpo explains further:

> So we see how an original quest for formal continuity in architecture, born in part as a reaction against the deconstructivist cult of the fracture, ran into the computer revolution of the mid-nineties and turned into a theory of mathematical continuity ... Without this preexisting pursuit of continuity in architectural forms and processes, of which the causes must be found in cultural and societal desires, computers in the nineties would most likely not have inspired any new geometry of form.[7]

Throughout the 1990s the British journal *AD* formed a critical avenue for disseminating these design approaches and ideas (and continues to be a leading avenue for advancing a digital design practice). This period can best be summarised as a move from 'the representational as the dominant logical and operative mode of formal generation' to a focus on performative and material investigations of topological geometries.[8] Accordingly, core design concepts such as 'representation, precedent-based design and typologies' are replaced by a new interest in 'generation, animation, performance-based design and materialization'.[9]

Defining theoretical concepts

By the beginning of the new millennium, theories of architectural digital design practice were becoming more articulated, distilling into defined theoretical concepts. Frédéric Migayrou's symposium Non-Standard Architecture held at the Centre Pompidou in Paris in 2003 is recognised as a defining moment, along with the influence of discourse emerging from the Venice Architecture Biennale in 2000 and 2004.[10] The three concepts of topology, parametric design and performance emerge, and are commonly acknowledged as foundational to a digital design practice. These concepts are introduced in the following section, and will be revisited in more detail in following chapters.

Topology

The concept of *topology* has its origins in mathematics and is understood as the study of geometrical properties and spatial relations which remain unaffected by changes in size and shape. For example a topological map (as distinct from a topographic map) is a simplified diagram that may be developed without scale, but still maintains the relationship to points. The London Underground map is an example where the map remains useful despite the fact that its representation shares little resemblance to a scaled plan of the Underground.[11]

Topology therefore offers a non-geometric manner in which to conceive space premised on the geometry of position.[12] Topology departs from an understanding of space as Cartesian (where each point is identifiable by fixed coordinates) to instead embrace topological properties of space that encompass surfaces and volumes. A topological approach, often described as 'rubber sheet' geometry, evolves from the application of pressure on the outside of surfaces through modifying algorithms. The resultant surface-driven architectural forms became known as BLOB or Binary Large Objects Shapes, defined as the development of a mass without form or consistency. Within this framing 'formation precedes form' with design generation emerging through the logic of the algorithm, 'independent from formal and linguistic models of form generation'.[13] This shifts design thinking from a visual or compositional judgement to a focus on relational structures represented within codes, algorithms and scripts.

Parametric modelling

The adoption of algorithms in form making introduces a *parametric* approach to design, which is considered the dominant mode of digital design today. Algorithms define a specific process which offers sufficient detail for the instructions to be followed. They are also known as script, code, procedure or program, terms which are often used interchangeably. Similarly, parametric modelling can also be referred to as associative geometry, procedural design, flexible modelling or algorithmic design. In this book we adopt the term parametric modelling. So how is parametric modelling applied in the design of the built environment?

Traditionally, design emerges through the making and erasure of marks, which are linked together by conventions. But within parametric modelling the marks of design 'relate and change together in a coordinated way'.[14] Rob Woodbury notes that:

> No longer must designers simply add and erase. They now *add*, *erase*, *relate* and *repair*. The act of *relating* requires explicit thinking about the kind of relation: is this point *on* the line, or *near* to it. *Repairing* occurs after erasure, when the parts that depend on an erased part are related again to the parts that remain. Relating and repairing impose fundamental changes on systems and the work that is done with them.[15]

However, is this an adequate explanation? Daniel Davis for example argues that Woodbury's definition doesn't explain how the relating of marks differs from other forms of parameter driven modelling such as Building Information Modelling (which will be discussed in Chapter 5).[16] He offers an alternative definition of parametric design:

> A parametric model is unique, not because it has parameters (all design, by definition, has parameters), not because it changes (other design representations change), not because it is a tool or a style of architecture, a parametric model is unique not for what it does but rather for how it was created. A parametric model is created by a designer explicitly stating how outcomes derive from a set of parameters.[17]

From these two definitions, it can be seen that a parametric approach to design places emphasis on 'describing relationships between objects establishing interdependencies and defining transformational behaviour of these objects'.[18] In short, the importance of composition, geometries or shape is replaced in parametric design by the declaration of specific parameters or rules for a design outcome. For example parameters related to landscape architecture could encompass achieving particular ecological or spatial conditions.

However, it is not simply the selection of parameters. Davis reminds us that 'the pivotal part of a parametric equation is not the presence of parameters, but rather that these parameters relate to outcomes through explicit function'.[19] In other words, the establishment of parameters within prescribed relationships.

On one level parametric design processes are highly structured, but at the same time they also encompass a high level of uncertainty and complexity. Importantly, they do not defer design generation to the computer, which instead remains within the domain of the designer. Branko Kolarevic offers a clear articulation of this approach to design generation stating:

> The capacity of parametric computational techniques to generate new designs is highly dependent on the designer's perceptual and cognitive abilities, because continuous, transformative processes ground the emergent form (ie its discovery) in qualitative cognition. The designer essentially becomes an editor of the generative potentiality of the designed system, where the choice of emergent forms is driven largely by the designer's aesthetic and plastic sensibilities.[20]

The generative potential of parametric modelling will become clearer in later discussions of design examples.

Performance

The third change associated with this transformative period is *performative* design. Broadly speaking, performative design shifts attention from what a design is, to what a design does. So far, out of the concepts introduced in this chapter, performative design is the least foreign to a landscape architecture audience, evident in late twentieth-century landscape architecture discourse. For example, in his Introduction to the edited volume *Recovering Landscape: Essays in Contemporary Landscape Architecture* published in 1999, James Corner advocates for the shift 'from landscape as a product of culture to landscape as an agent producing and enriching culture'.[21] Focus moves from 'landscape as a noun (as scene or object)' to instead 'landscape as verb' (how it works and what it does).[22]

Within the context of a digital design practice, appearance and performance become increasingly blurred as digital tools increase the capacity to link analysis, generation and performance.[23] At a theoretical level, the concept of 'affect' emerges, which questions 'the separation between object and subject'. [24] Borrowing from the philosophical writings of Deleuze and Bruno Latour, digital designers explore continuity, through concepts of 'active agency', where architectural affect is produced through 'continuous interaction between subjects and objects'.[25] This thinking has evolved into performance-orientated architecture, 'based on the understanding that architectures unfold their performative capacity by being embedded in nested orders of complexity and auxiliary to numerous conditions and processes'.[26] Put

1.2
Yokohama Port Terminal designed by Foreign Office Architecture in 1995.

more simply, 'the building *is* its effects, and is known primarily through them, through its actions or performances'.[27]

Approaches to performance in architecture have been aided by computational techniques such as scripting and simulation that provide a more comprehensive understanding of effects and outcome. While landscape architecture has been interested in performance theoretically, its resistance to these computational techniques has until recently limited its ability to explore performance as part of design processes.

The convergence of the three concepts of topology, parametric modelling and performance is evident in a number of urban design projects constructed in the late 1990s. Of most note is the Foreign Office of Architecture's (FOA) 1995 design for the *Yokohama Port Terminal* shown in Figure 1.2, which has been acclaimed as 'one of the most meaningful architectural achievements of the digital age'.[28] FOA identify two driving ambitions for the project: first, 'an interest in the *performative* approach to material practices, in which architecture is an artefact within a concrete assemblage rather than a device for *interpreting or signifying* material and spatial organisation', and second 'the construction of a model which is capable of integrating differences into a coherent system'.[29] These agendas combined in the conceptualisation of the port terminal as:

> a mediating device between the two large social machines that make up the new institution: the system of public space of Yokohama and the cruise ship flow, reacting against the rigid segmentation usually found in mechanisms dedicated to maintaining borders.[30]

A continuity of surface and movement offers 'smooth connectivity' blurring the boundaries between internal and external spaces. Different segments of program operate 'throughout a continuously varied form; from local citizen to foreign visitor, from flâneur to business traveller, from voyeur to exhibitionist from performer to spectator'.[31] The folding surface provides for 'creases' that offer structural strength, 'like an origami construction', challenging the conceptual separation of load bearing structure and the building envelope.[32] Of particular interest to landscape architects is that, as noted by Stan Allen, the *Yokohama Port Terminal* 'is perhaps the most convincing realisation of an architecture invested in the idea of landscape techniques working at the scale of a building'.[33] According to Allen, the scheme 'operates almost entirely on the basis of the operative techniques of landscape design and the programmatic effects of continuous topological surfaces'.[34]

Yokohama Port Terminal, together with contemporaneous urban projects in Barcelona such as *South-East Coastal Park*, demonstrates how an exploration of topological spaces facilitated by new software led to significant architectural interest in the domain of landscape architecture, which continues today unabated. As discussed in the Preface, the architectural projects that dominate the content of the 2012 publication *Digital Landscape Architecture Now* reflect almost quarter of a century exploration of surface topology, parametric modelling and performance. The concept of landscape provided architecture with productive models of synthesis offering formal continuity, performative potential and programmatic flexibility.[35]

Importantly, these new theoretical concepts for design generation coincided with what is described as 'the Direct Manipulation Boom' in technology, which reduced the necessity for designer's to engage directly with mathematical understandings of algorithms. Increasingly software interfaces offer 'tool-like operations' which modify space and form in real-time onscreen.[36] Discovery occurs through 'manipulation rather than derivation through formulas', although the formulae remains embedded within the software.[37] The digital realm is now accessible to non-specialists, allowing surfaces to be modelled in an intuitive manner, with real-time feedback or 'applied with a geometric rationale'.[38] The development of a visual language of scripting such as Grasshopper (which emerged in 2007), further progresses the designer's ability to intuitively build scripts to generate and test form without extensive mathematical knowledge. Designers are liberated from mathematics, while at the same time form making is liberated by mathematics.

Similarly, there has been a rapid evolution of hardware capacity. Personal computers and laptops were common within the design office by the early 1990s. The Macintosh Classic for instance was released in 1990, and was the first Apple product priced below US$1000. Correspondingly, data storage has increased in size and decreased in price. In the early 1980s, 3.5 inch floppy discs held just 0.0002 GB of memory. By 1994 zip discs offered 0.098 GB, increasing to 32 GB by 2012 (courtesy of the smallest USB memory sticks), while the emergence of personal cloud computing since 2006 has radically transformed file storage and sharing.[39]

All of these changes significantly altered the designer's capacity and relationship to technology. But unquestionably, one of the most significant technological developments for landscape architecture is the evolution of 3D modelling capabilities of software from vector based techniques, well suited to the design of objects, to meshes, polygons and NURBS (non-uniform rational b-splines) which are of great value to the modelling of topography.

Modes of surface modelling

Modelling (whether virtual or physical) has not featured as prominently in the design processes of landscape architecture as in other disciplines such as architecture and industrial design. A handful of designers are well known for their use of physical clay models as form generators; notably Kathryn Gustafson and George Hargreaves. In his role as Chair of the Landscape Architecture Department at Harvard, Hargreaves introduced a clay landform workshop as a compulsory part of the curriculum. To Hargreaves the physical model is invaluable in exploring the pure form of slopes, shapes and intersections, not as a measure of how these forms work within an existing site, but rather to understand their implications.[40]

Early versions of 3D digital modelling could not match the speed or form-making abilities of physical models. Initially, modelling techniques were constrained by the limitations of vectors which formed the means for the construction of objects within digital space. Represented by lines and points that have a quantity of direction and/or force, vectors operate within a 2D or 3D coordinate system. A vector-based system offers a restricted engagement with non-Euclidean surfaces with modelling techniques limited to the functions of addition, distancing, scaling and multiplication.

The open source program SketchUp (first available in 2000) offered one of the first general purpose user-friendly 3D programs, originally known for its rectilinear and 'blocky' form-making derived from the pushing and pulling of shapes and surface vectors. The linear nature of the extrusions and spatial manipulations required the user to complete extensive small operations to generate more irregular form.

The introduction of polygons and meshes within 3D modelling programs provided a more complex and 'landscape friendly' engagement with surface. Mesh surfaces are made through the joining of polygons to form geometric units, with the density of the polygons influencing the accuracy and detail of a surface. The mesh is manipulated through the modifications of points, with the smoothness of curves and geometries a factor of the number of points and lines within a mesh. This geometric

1.3a–b
Folded landscape at the *Laban Dance Centre* designed by Herzog & de Meuron with Vogt Landschaftsarchitekten in 2003.

domain establishes controls of 'faces', 'edges' and 'vertices' as the major modes of spatial manipulation. Andrea Hansen, in her article 'From Hand to Land: Tracing Procedural Artifacts in the Built Environment', highlights a number of constructed landforms, predominantly among 'architect-designed landscape projects', which read as faceted surfaces reflective of their form generation within a triangulated mesh modelling program. These include FOA's *La Gavia Park* and the design of *Laban Dance Centre* by Herzog & de Meuron and Vogt Landschaftsarchitekten, as shown in Figure 1.3.[41]

The introduction of NURBS (non-uniform rational B-spline) significantly increased the ability to work with both standard and free-form geometries. These curves and surfaces first emerged in the 1950s as engineers sought more precision in 'the description of free-form surfaces such as ships' hulls and car bodies'.[42] Pierre Bézier who worked for Renault, was influential in the development of the algorithms of uniform non-rationale B-splines, recognised in their alternative name of Bézier splines. Returning to the earlier reference of 'rubber sheet geometry', curvilinear topological surfaces can be described as NURBS. These afford the designer a high degree of control through the manipulation of weights, knots and control points. In a very few steps, designers can weight, fix or manipulate these control points, offering speed and precision in creating and understanding complex geometries in a systematic and linked manner.[43] NURBS state Antoine Picon 'are emblematic of the creative space opened up by modelling', allowing designers to interact with curves, spaces and volumes in a 'highly intuitive way'.[44]

It is generally considered that polygon modelling best suits defined hard-edged objects while NURBS are more useful for curved smooth forms. However, this depends very much on which program is being used. For example the Autodesk program Maya has an extensive range of polygon editing tools alongside powerful NURBS tools.[45] In comparison to NURBS, polygon modelling offers a reduced description of a surface, which often sees designers working faster and more intuitively with polygon surfaces, before transferring their designs into NURBS modelling programs such as Robert McNeel & Associates' software Rhinoceros (known popularly by the shorter term Rhino) to produce a more detailed model. A NURBS model also offers a slower real-time speed of interaction when compared to polygon modelling.

Sitting between NURBS and polygons are hybrid tools of subdivision that permit the merging of mesh and NURBS characteristics within the same model (Figure 1.4). Subdivision tools allow designers to use polygons for speed of modelling and to develop accurate locations for important points within a design, with NURBS then applied to add detail and 'smooth' out interstitial spaces between the polygon entities.

Some programs such as Maya have inbuilt parametric capabilities, while others such as Rhino require plug-ins like Grasshopper to perform in more parametric ways. Parametric capability (which will be discussed in far more detail in Chapter 2) includes the precise recording of command history, which offers the

1.4a–c
Three different modelling surfaces: (a) NURBS, (b) polygons and (c) subdivision.

designer the ability to alter defined parameters. As software programs continue to evolve, this brings new capabilities and refinements to designers. Increasingly software is becoming similar, although with varying degrees of complexities. SketchUp for example is now available with a NURBS plug-in.

For a new generation of landscape architects trained within a 3D context, the digital realm offers a design platform as intuitive, creative and explorative as the clay models favoured by earlier generations. Further, the development of laser cutters, CNC routers and 3D printing and scanning hardware reverse more traditional information and production flows introducing 'dual directional' design processes.[46] Designers can transform a physical model into a digital model and vice versa, which encourages continued and faster design explorations. The cost of these fabrication techniques has also reduced significantly over the past 5 years, encouraging their application within design processes, as distinct from being used only as final presentation models. For example it is now possible to buy small CNC routers and 3D printers for less than US$1000, allowing them to be relocated from workshops and Fab labs, to be positioned directly next to the designer's desk.

In a process not too dissimilar to traditional modes of model making, a laser cut model is made through the cutting of components from a sheet, which is then manually assembled into a 3D model. Computer Numerically Controlled (CNC) milling and routing introduces a particularly valuable process for landscape architecture, replacing stepped laser cut models (which emphasise the contour rather than the slope which is referenced by the contour) with a continuous surface which offers a more accurate understanding of topography and land form. CNC milling works through the removal of material from a volume in a process similar to carving from a block. This highly accurate and detailed process is particularly useful for flatter landscapes which are difficult to understand and represent within standard analogue representational techniques such as sections and plans. In analogue sections and stepped contour model, it is not uncommon for landscape architects to exaggerate landform in order 'to see' topographic form. However the accuracy and detail of the CNC routed model offers an excellent representation of subtle surface manipulations, down to the level of a surface inscription. As shown in Figure 1.5, topography as represented in laser cut models is still influenced by the depth of material used to layer the model. This is no longer a factor within the CNC model where attention is focused on the qualities of the slope rather the exaggeration of the contour.

A 3D printer which uses a modified inkjet print head with a hardener produces a similar result. The form builds as the printer passes in successive runs, adding material in layers. This additive process produces less waste than the reductive process of CNC milling. Models are generally small. However more recently, architects have begun to explore 3D printing for fabrication. For instance, in early 2013, Dutch architecture studio Universe Architecture announced their ambition to 3D print an entire house using sections ranging up to 6 x 9 metres.[47]

Tangible User Interfaces offers a further example of digital model production. Since the early 2000s the Tangible Media Group at the MIT Media Lab has

been exploring the intersection of haptic (tactile feedback) and digital modelling. Illuminating Clay (2002) followed by Sandscape (2003) combine 'dynamic sculpting and computational analysis using digitally augmented continuous physical materials'.[48] More recent software developments allow such explorations to occur with minimal cost. Conventional sand for example can be used with a Kinect scanner (developed by Microsoft as part of their Xbox game console) and customised software to establish an interface between physical modelling and a digital elevation model.[49]

This brief introduction to the evolution of 3D modelling software and associated fabrication technologies highlights the transition from vector-driven models to meshes and NURBS. In the second part of this chapter we turn our attention away from architecture to focus on contemporary landscape architecture

1.5a–c
Digitally produced topographic models with different level of surface refinement: (a) stepped terrain of the laser cut model, (b) the smooth slopes of a CNC routed model and (c) a detailed 3D printed model.

1.6a–b
Workshop laboratory at ETH Zurich: each modelling station consists of a sandbox, a 3D scanner and a computer with display monitor. Students use the sandbox set-up during the design process for modelling conceptual ideas and for presenting their design.

practice to explore their application of 3D modelling techniques primarily in the design of topography. Here we begin to see some disciplinary differences in the manner in which landscape architects engage with concepts of performance, topology and parametric modelling. To landscape architecture, topology represents far more than an abstract surface or a mathematical construct. Christophe Girot in his landscape-driven definition of topology identifies a three-tiered approach encompassing structure (geomorphological and infrastructural), surface (cultural organisation and production) and atmosphere (immaterial aspects).[50] As we will explore in the following section, landscape architecture's engagement with sites positioned within a cultural and ecological continuum in constant flux creates different opportunities and potential for parametric modelling.

Generative topography

As we outlined in the Introduction, landscape architecture has been reluctant to shift from the familiarity of the 2D plan into the design potential of 3D modelling. Girot comments on landscape architecture's considerable complacency in regard to representational techniques stating 'we are apparently content with a status quo that has prevailed in landscape architecture over the last forty years'.[51] For example, *Visualising Landscape Architecture*, although published in 2010, continues to champion the 2D plan as the major design representation to 'provide a basis for all further representations of the design ideas'.[52] Writing in 2008, Peter Walker observes the privileging of 'the horizontal dimensions of landscape' over the vertical, commenting that many landscape architects consider the plan 'sufficient to represent spatial relationships, grading and layout, and the disposition of plant materials'.[53]

The continuing primacy of the plan view is surprising, given that understanding topography (a distinguishing feature of landscape architecture) within 2D is particularly challenging. Not only is the plan a highly abstracted mode of representation requiring spatial literacy to interpret the information as 3D space but the aerial perspective creates considerable distance between the spatial configuration and experiential quality of the design. This is even more evident when it comes to the use of contours to represent 3D landforms, which only enables 'a trained eye to visualize the shaping of the land'.[54]

This limited use of 3D digital modelling in the discipline of landscape architecture has meant that many design firms interviewed as part of this research prefer graduates who have dual qualifications in architecture and landscape architecture. The architectural background, comments Snøhetta's director Jenny B. Osuldsen, equips graduates with a stronger understanding of 3D space.[55] Encouragingly, this weakness in landscape architecture is changing as more and more landscape architecture courses incorporate 3D modelling within their curriculum. However, to be most effective, this shift in teaching requires a more fundamental revision of design curriculum than simply 'adding' digital tools to existing representational courses.

Landscape curriculum conventionally separates design studios, technical knowledge (grading and engineering) and graphic communication. Often the introduction of digital technologies occurs within the graphic communication courses, presented as an extension of 2D representational techniques. But as Brian Osborn from the University of Virginia comments, this isolation of digital technologies from design studios makes it difficult for students 'to make meaningful connections between digital media courses and the other course work'.[56] Without direct engagement, students find it difficult to apply their new knowledge and techniques to design, which further limits their ability to discover new applications for the software on their own during the design process.[57] Significantly, this separation fundamentally disrupts the potential of 'a continuous logic of design thinking and making', which, as we discussed in the Introduction, forms a critical characteristic of

a digital design practice.[58] Throughout this book, we offer guidance on how to best introduce and situate digital technologies within pedagogy to maximise its potential as a design tool. These ideas are informed by a close analysis of how digital tools alter workflows, design approaches and construction processes, combined with observations from academics experienced in this teaching.

In the following section we introduce two ways that practices have engaged with digital 3D modelling. As examples, we begin with the precise topological surface of LAAC's *Eduard-Wallnöfer-Platz* followed by PARKKIM's scheme *Mud Infrastructure*, which engages land form and dynamic water systems. Within these schemes, 3D modelling helps the designer to visualise and generate complex surfaces and forms. While producing novel and interesting form, strictly speaking these modelling approaches are not considered computational design. This difference becomes clearer through the discussion of the latter examples – ASPECT Studios' design of the *Victorian Desalination Plant* and Snøhetta's scheme for *MAX Lab IV*. Here the digital model assumes a very different role, reflective of a computational approach. The model is more formational than representational with the designers applying a rule-based parametric design approach.

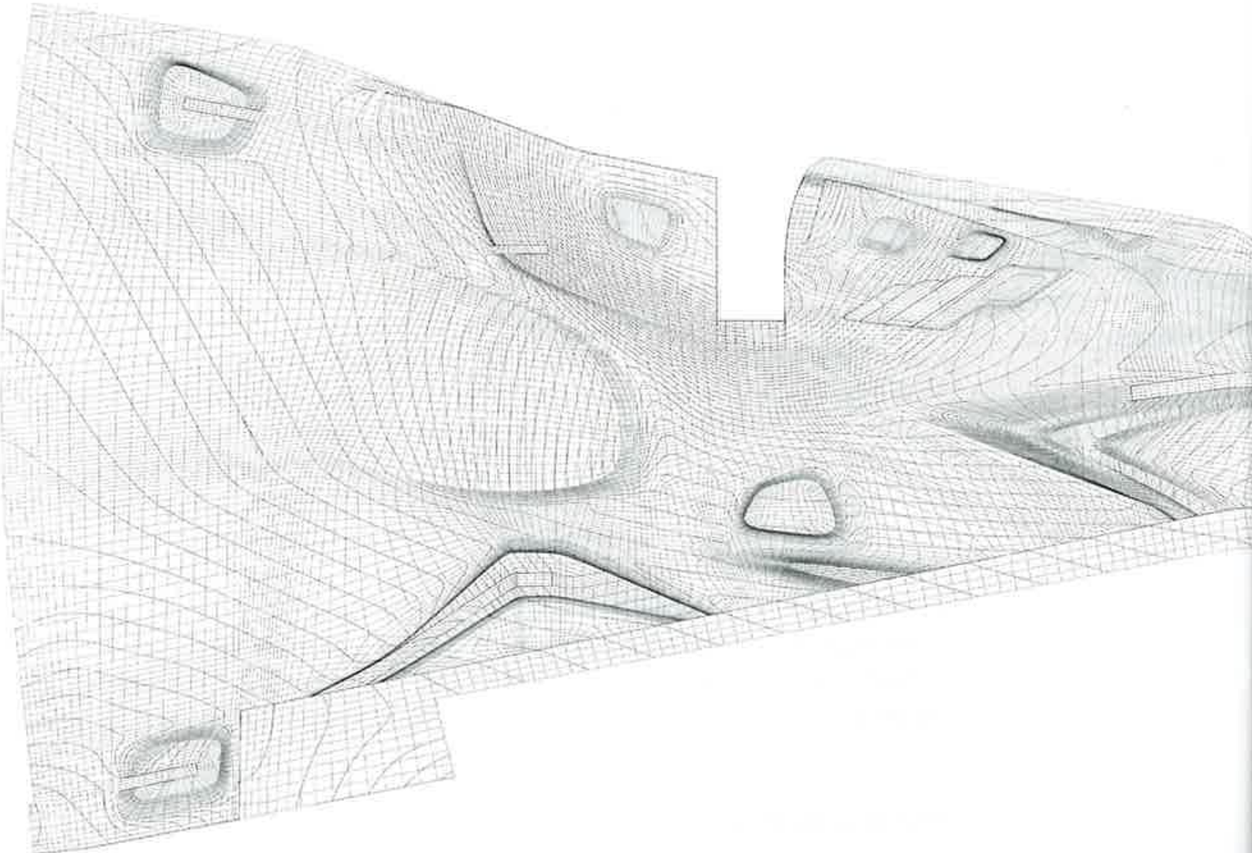
Precise geometries

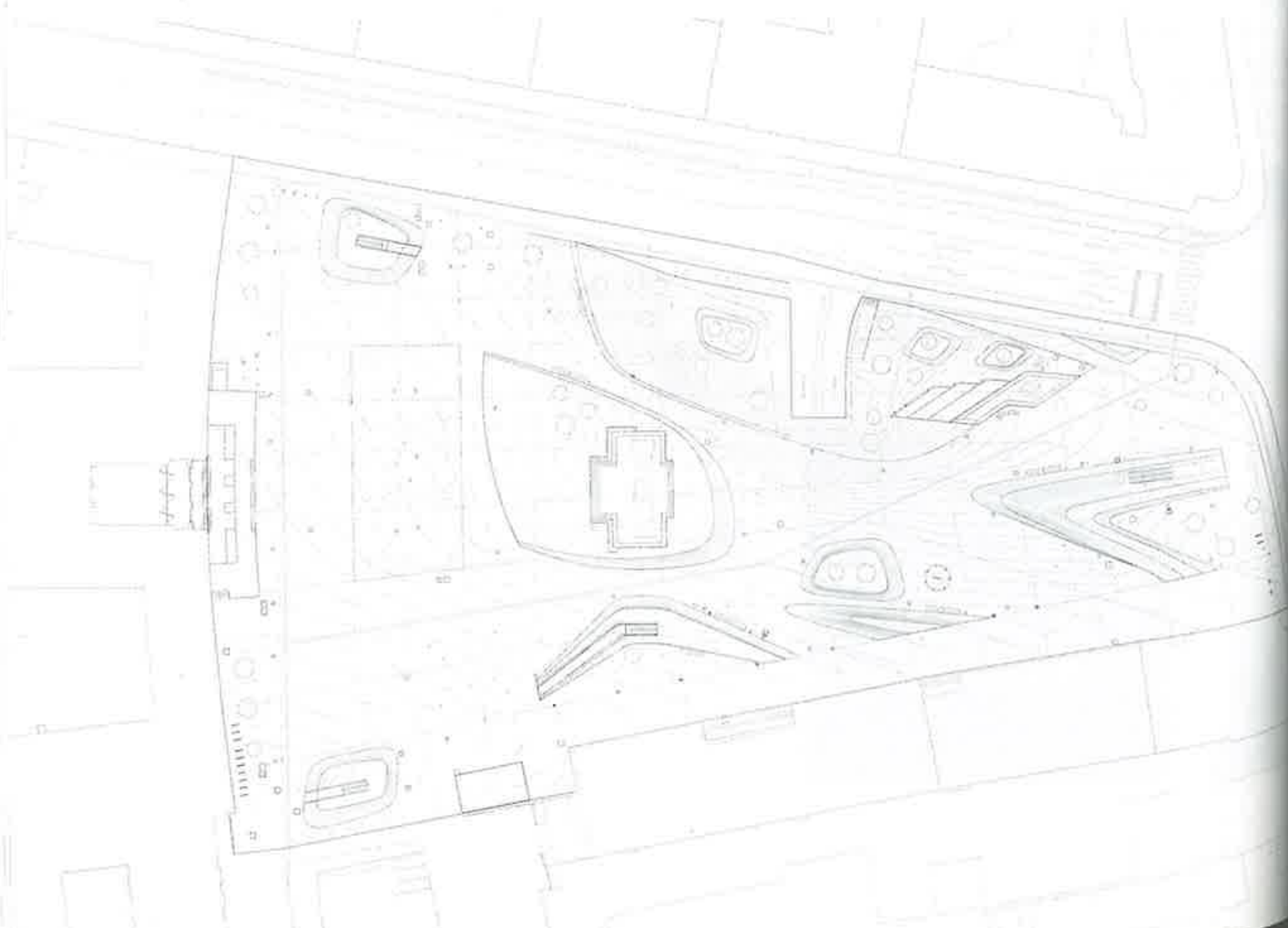
In 2008, the Austrian design firm LAAC won an invited multi-stage design competition for *Eduard-Wallnöfer-Platz* (also known as *Landhausplatz*) for the largest public square in Innsbruck, Austria. Over time this site (Figure 1.7) had evolved into two disparate spaces: a small flat grass parkland fragmented by a series of memorials sited along a central axis and a car park which operated as a forecourt to the Tyrolean provincial governmental building. In a further complexity, a subterranean garage was constructed under 80 per cent of the space. The new square needed to address the conflicting language and meaning of the monuments, in addition to developing a social space for a square that had no active edges.

1.7
***Landhausplatz*, Innsbruck's largest public square prior to the transformation. In the foreground: the liberation monument.**

LAAC proposed a bold sculptural topographic form, with the ambition to 'use new geometries in new ways'.[59] No community consultation was undertaken, with the designers instead believing that innovative form would 'influence people and their use'.[60] Inspired by the metaphysical painter Giorgio de Chirico's reflections on power and freedom, particularly *Place de Italia* (1913), the designers also looked to the potential of shadow and light to develop a complex surface, which positioned the user as a 'protagonist on a stage'.[61]

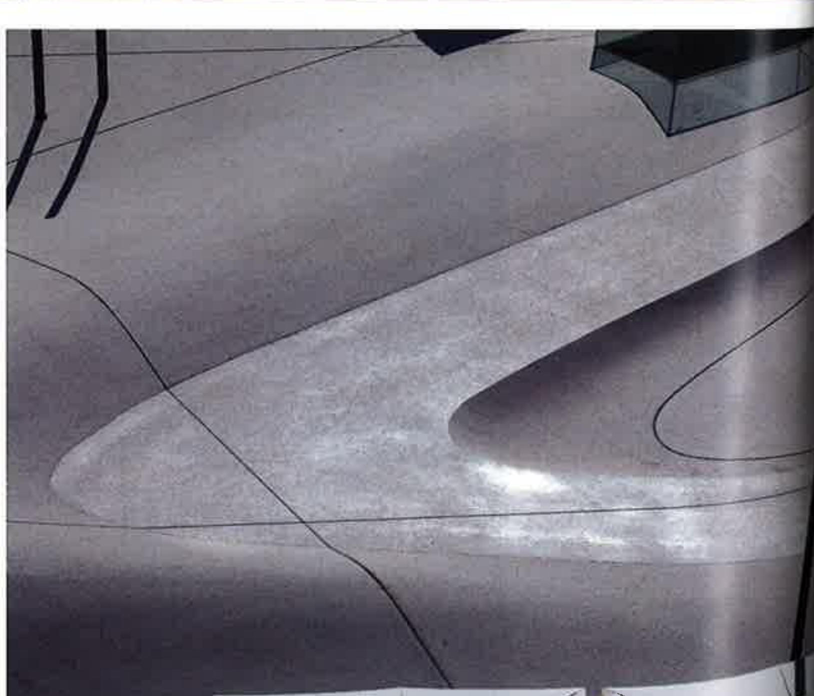
The competition entry was developed using Maya software, permitting the designers to work quickly and intuitively to explore multiple iterations of the surface. The 3D





1.8a–b
LAAC's 3D modelling process: The scheme was initially designed using Maya software (a) then further refined in Rhino and developed into documentation using AutoCAD (b).

1.9a–b
Unidirectional lighting at night produces a uniform bath of light, without delineating a set path. The decision to not light the façade of the government building further reinforces the primacy of the topographic surface at the front of the government building.



1.10a
The new surface transforms the base of the large memorial into a continuous surface that sweeps over the top of the car park entrance and into a flat multi-functional area featuring a large fountain in summer.

1.10b–c
The ambition to develop a transformative topography extends throughout the detailing, apparent in the subtle changes of concrete texture to reflect different performance parameters offering places for people to sit, skate and walk.

model offered a clear articulation of form, including the ability to understand light and shadow. The subdivision tool was used to create denser polygon meshes on the chiselled edges of the forms, while maintaining smooth NURBS surfaces in other areas. After winning the competition, the design was further evolved using Rhino. Working with more detailed site data from the surveyor, a higher level of accuracy was introduced into the curves, junctions and tangents that comprised the complex surface. The Rhino model was eventually taken into AutoCAD to produce the sections and details required for construction.

The modelling process aided the designers in conceiving a continuous surface which operates as a tactic for engaging with the ambiguous language and meanings of the existing memorials, particularly the large central memorial constructed by the French military government (as occupying power) at the end of the Second World War (1946–8). Conceived in recognition of the people who lost their lives in fighting for the liberation from National Socialism, the memorial's design problematically replicates the fascist language of the Tyrolean provincial governmental building.

LAAC's approach exemplifies the concept of Lynn's 'smooth transformation', discussed earlier in the chapter.[62] This continuous topological terrain offers a 'contemporary and transformative base for the memorials',[63] dislodging them from their central axis and defusing the symbolism of the main monument by absorbing part of its stairs into the topographic surface. This spatial move disrupts the fascist highly symmetrical design language while creating more prominence for the other memorials found on the site, including the menorah that references the murder of four Jewish citizens of Innsbruck during Kristallnacht.[64]

Initial reactions to the constructed square were tentative, with many older residents dismayed by the absence of grass.[65] Very quickly the potential of the new geometries were recognised by the skating community, locally and internationally. Their enthusiastic use of the square however raised issues concerning liability. In 2011, the Free *Landhausplatz* site was established on Facebook, in response to potential threats to ban skating. This lobby resulted in two shifts. First, the square's reclassification from a public square to the status of 'street without cars' which shifted liability to the user, and, second, a negotiation with skaters to develop a 'behaviour codex'. This codex establishes the square as 'a place for urban encounters and not a skate park' and aims to 'find compromise and not prohibition' to allow all uses in cooperation.[66] This agreement includes not skating on sensitive areas such as the front of the government building and the top of the memorials. The success of this negotiation is reflected in the following statement from the Free *Landhausplatz* site: 'let's do everything together to get the *Landhausplatz* as a central meeting place where everyone can do anything, as long as it does not harm anyone else'.[67]

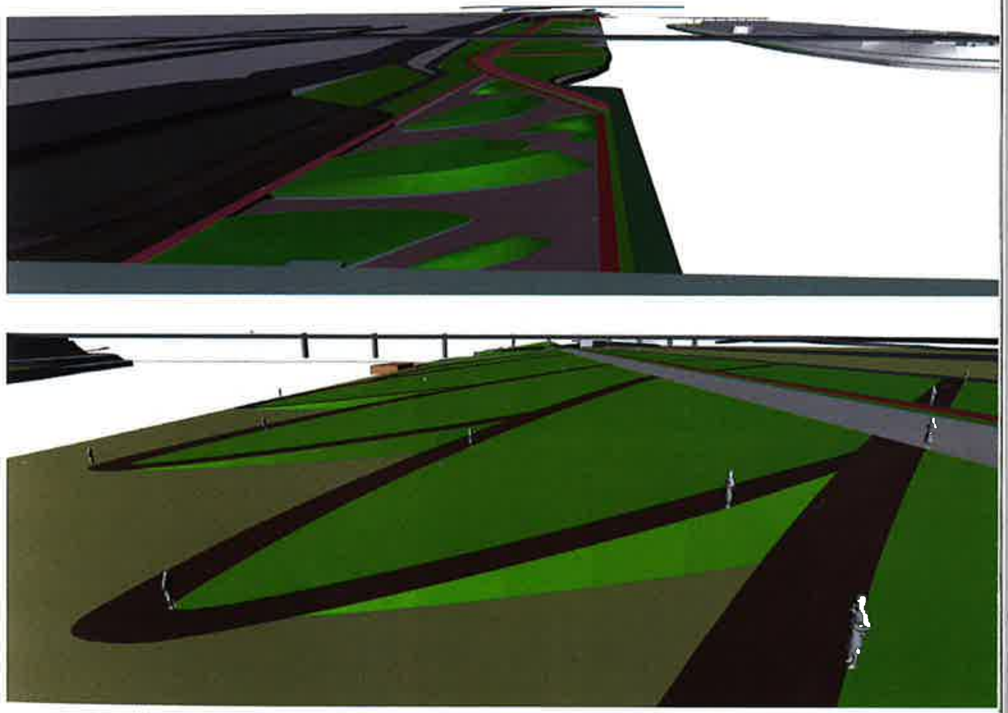
The intent to promote new use through innovative geometries inspired a more profound renegotiation of civic space, including the revision of regulations and acknowledgement of civic responsibilities, which perhaps would not have occurred if the designers had undertaken a more predictable community consultation process. Invariably these processes edit out possibilities and innovation leading to a compromised position after all interested parties assert their, often polarised, views. Alternatively, aided by the considerable form-making capability of 3D modelling, and influenced by theoretical concepts of topology and performance, the designers produced a novel form that not only instigated change but also heightened the ambition for public space.

LAAC's interest in performative topological surfaces can be further expanded to incorporate considerations of ecological performance in the landscape. It is generally understood that water management is one of the most dominant rationales for topographic manipulation in landscape architecture. In the following example, we explore how the South Korean-based design firm PARKKIM combines 3D modelling with dynamic hydrological processes to develop their scheme *Mud Infrastructure*.

Landform systems

This project is the winning proposal in a 2009 design competition for a 2km long and 100m wide park in the Yanghwa area of the Han River. Initiated by former mayor Oh Sehoon as part of the second phase in the Han River Renaissance, the competition aimed to revitalise the river's embankment system into a new public park. Under Oh Sehoon's leadership Seoul heavily invested in citywide design-led urban regeneration processes, unprecedented in the Asian context. In this aspect, the Han River Renaissance project is the first of its kind in South Korea to allow landscape architects to conceptually lead the renewal of a major infrastructure as opposed to the engineering-focused solutions that dominated the city's development until well into the 1990s.

While this was a great opportunity for the profession, most competition proposals merely resurfaced the existing levee and introduced new circulation routes. In contrast, PARKKIM embraced the challenges by reconceiving the new park as *Mud Infrastructure* – a responsive infrastructure that facilitates use even during the time of flooding. The project embedded hydrological principles that would allow the project to operate at any time during the year, while also addressing the massive amount of sediments deposited after the floods.

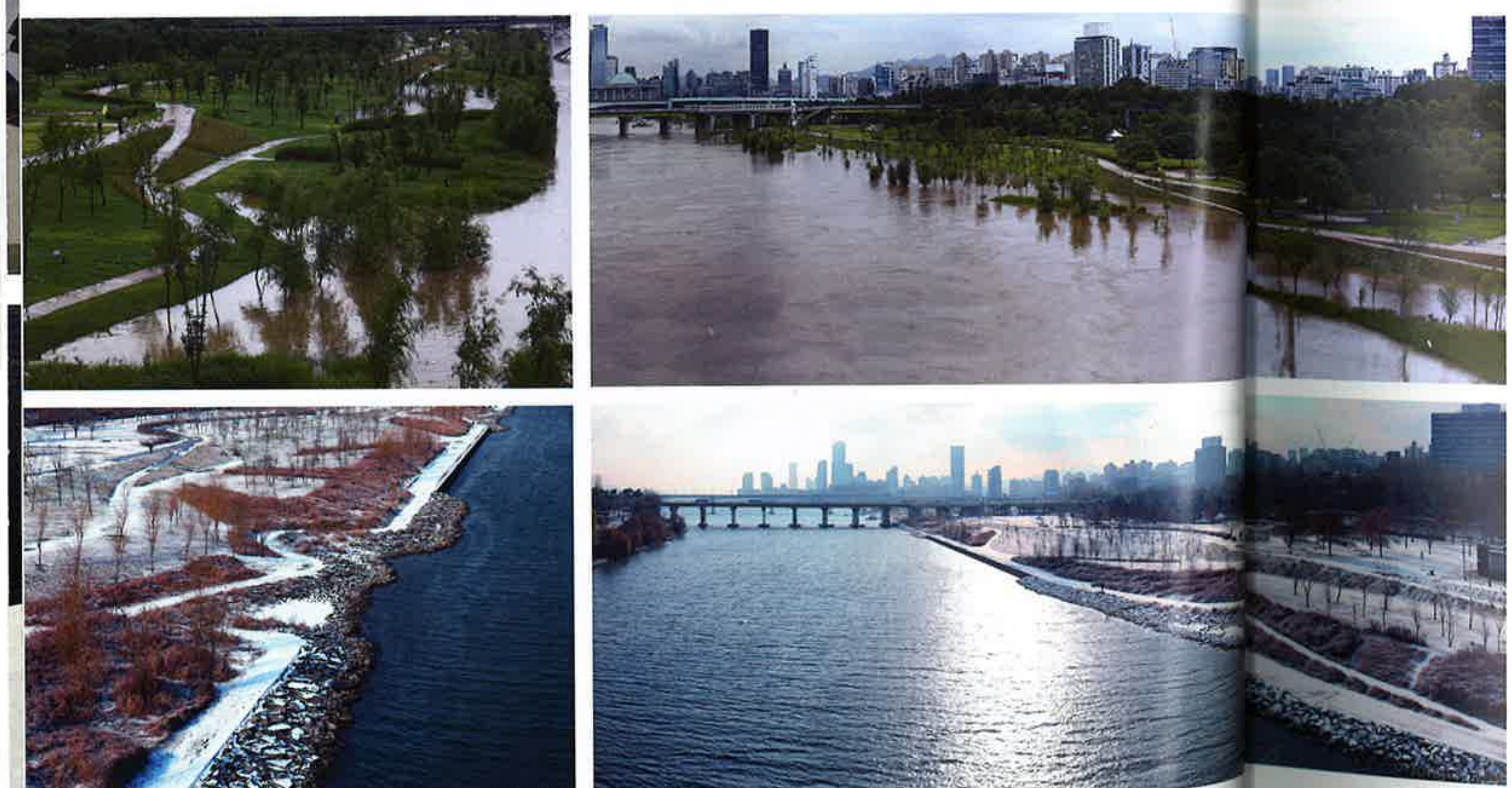


1.11a–b
Initial topographic explorations of path and slope gradients conducted in Rhino.

1.12
Mud Infrastructure reconceptualises the river's edge from highly engineered concrete levees into a dynamic landscape.

The site was challenging. The Han River is 1 kilometre wide as it runs through the centre of Seoul and is notorious for its dynamic hydrology and destructive floods that have profoundly shaped the city for centuries. Influenced by both daily tidal changes and high precipitation during the yearly monsoon season, the conditions change the river from shallow waters with extensive mudflats to deep and dangerous currents in early summer. This condition is amplified by the extreme concentration of slit and grit deposits, built-up from soil erosion in the mountainous areas further upstream, resulting in extensive costs for cleaning infrastructure along the river including parking lots, paths and highways. For instance, after the flood in 1990 sediments of between 0.1 and 1.5m deep covered most of the flood plain, requiring cleaning costs of approximately US$7 million.[68]

Addressing the existing levee structure that dominates the entire embankment along both sides of the river was a major issue for the design. Introduced in the 1960s to mitigate the destructive floods that would destroy vast areas of the historical city to the north, as well as threatening new residential developments to the south, the levees were constructed as a massive concrete infrastructure consisting of three terraces. Each terrace level contains a maintenance path that runs parallel to the river and is separated by a steep concreted slope. While the structure is partially successful in controlling floods, its linear and even slopes heavily facilitate the accumulation of deposits. Thus, PARKKIM's proposal challenges the existing layout by forming a new topographic surface that engages with the hydrological dynamics and sedimentation processes. Similar to LAAC's scheme for *Landhausplatz*, 3D modelling played a central role in creating a continuous geometry that offers a seamless flow line from the lowest water level to the higher embankments.



1.13–14
Mud Infrastructure inundated by flooding in early summer and covered in winter snow. Note that the path system remains usable during the floods.

Driven by the three considerations of sedimentation, program and circulation, the designers reconstructed the new surface as a series of slopes with a variety of lengths and inclinations ranging between 4 and 13 per cent. A pathway system graded to a maximum slope of 5 per cent was designed to intersect these slopes and provide barrier-free access to the entire park. The shallow slopes not only support better accessibility and circulation in the park but are conceived to be beneficial in removing excessive sedimentation built up after storms. Achieving a smooth overall surface required careful cut-and-fill operations, as extending the terraces out beyond the existing shoreline was deemed unfeasible.

These basic grading principles were first laid out in plan before being translated into Rhino to construct and test the entire landform in 3D. Although a relatively small practice, PARKKIM is very accepting of the potential of a 3D modelling program such as Rhino as a primary design tool to test and refine ideas. They consider the adoption of digital technologies as a necessary step in elevating their practice to an international level. These tests allowed the designers to control the modulation of the edge condition to respond to the fluctuations in water levels. A series of landforms which would encourage the formation of eddies were introduced to increase water circulation during a flood event, thereby preventing the build-up of sedimentation. In other parts the reconstruction of the concrete edge with a 'new riprap shoreline actively encourages sedimentation to build up new habitats for fish and birds'.[69] The new landform profiles subsequently define the program development and divide the park into various activation zones including a plateau, a riverine theatre overlooking the river and adjacent Seonyu Island, and wild hills with diverse undulating topography which form the entrance into the ecological area.

Initially only conceived as schematic design, the landform further evolved after the competition following consultation with a hydraulical engineer, who advised that the eddies be further exaggerated and the irregularity of the shoreline increased. The engineer was also required during documentation to testify that the proposed tree clusters would not have an adverse impact on the water flow and the river system. During this phase, the Rhino model was taken into AutoCAD for further detailing of the contour plan and to develop documentation drawings.

Although more advanced digital techniques would have allowed the designers to engage with the potential of parametric design and the simulation of these highly complex and dynamic environmental systems, *Mud Infrastructure* was not designed to accurately reflect the dynamic flow conditions, mainly because the yearly water and velocity levels were considered too unpredictable to produce reliable data.

However, since its completion in 2011 the park has been inundated multiple times and has already proved to be successful in preventing excessive sedimentation while also providing secure access to the park during the flood events as seen in Figures 1.13–14.

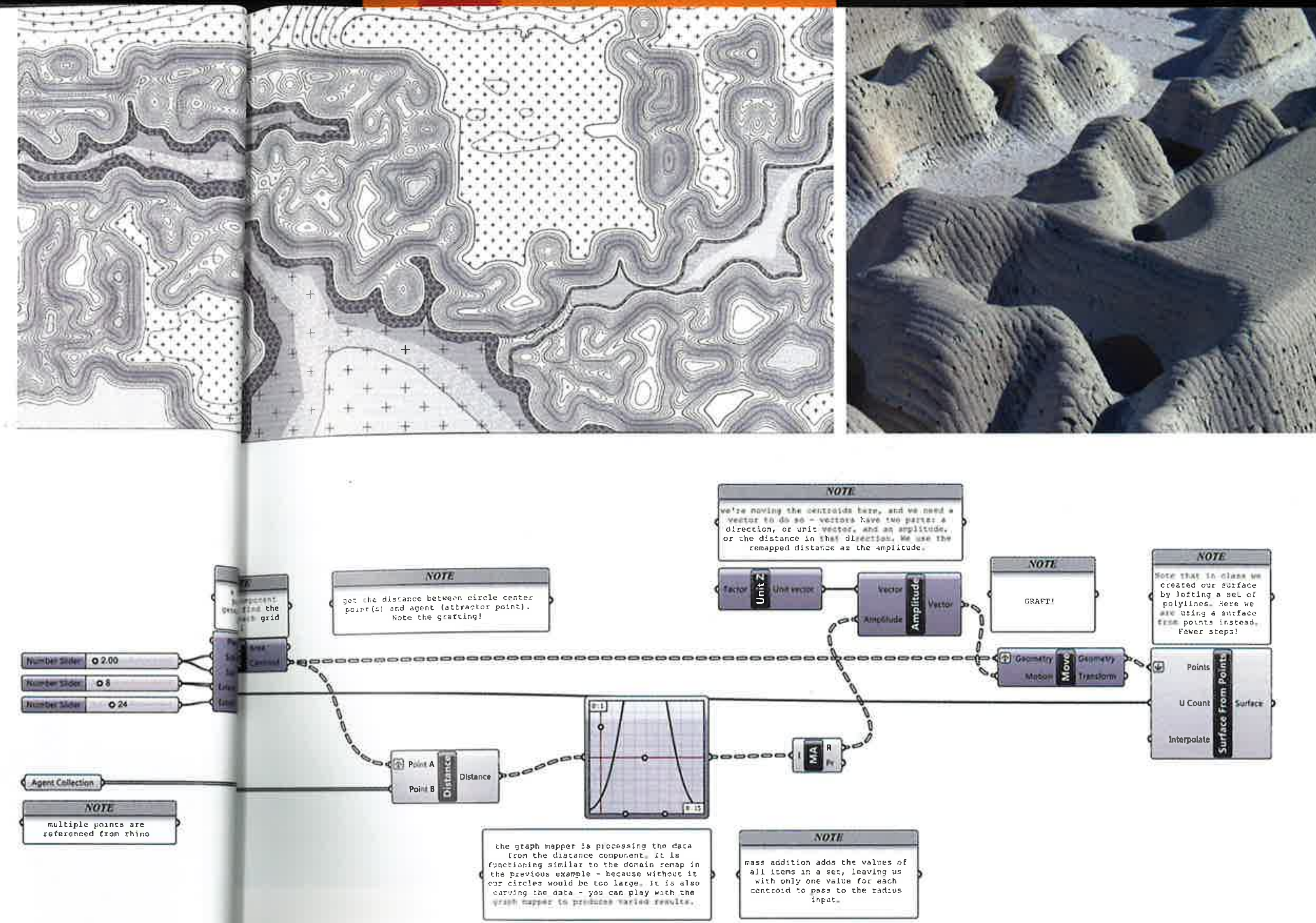
To some extent PARKKIM's design process resembles a basic approach to 3D modelling, where an initial design concept is explored, tested and refined within a 3D realm. This differs from LAAC's engagement, where the digital model assumes the primary mode for exploring and generating form. The manner in which PARKKIM currently operates, employing graduates proficient in digital techniques, to complement and extend the abilities of the two directors, is common in many landscape architecture firms. These design processes are reflective of a discipline in transition, positioned between a new generation increasingly comfortable with designing directly within 3D space and an earlier generation more familiar with analogue techniques or physical modelling. For example the celebrated landforms of the northern park at the London Olympics site were initially designed by Hargreaves Associates and LDA Design using physical clay models which were then explored in more detail through 3D Rhino models.

In the final part of this chapter, we move from the discussion of a digital model as a technique for exploring, generating and testing topographic form, to a rule based approach that fundamentally introduces a new logic to a design process through the potential of computational design.

Rule-based topography

Parametric modelling or a 'rule-based' approach to design is still quite rare within landscape architecture design practice and teaching. Interviewed practitioners and academics struggled to nominate examples of built projects generated through parametric modelling, beyond the design of components such as paving. In this chapter's final examples, we introduce two parametric approaches to topographic form making applied to the design of infrastructural landscapes. These complex large-scale schemes, which require designers to address specific parameters such as balancing cut and fill and the consideration of visual, hydrological and ecological implications, provide perfect scenarios in which to apply a rule-based approach to design. The first example by Australian firm ASPECT Studios applies what we define as a conceptual parametric approach in their design of the *Victorian Desalination Plant*, while the second example by Snøhetta demonstrates a more precise rule-based approach in their design of the *MAX Lab IV* in Sweden.

Before beginning this discussion, it is useful to consider how a rule-based approach to design is approached in the landscape architecture curriculum. There is much academic debate within architecture and landscape architecture concerning when and how to introduce parametric design (including the ability to script or code) to students. This design approach requires a particular type of abstract



1.15a–c
The land form *Wash* presented in plan and final model, together with a Grasshopper definition used as part of the form generation.

procedural thinking that is new to design education. The few landscape architecture courses that do introduce these concepts, do so in later years, instead focusing on 3D modelling such as Rhino (without a parametric emphasis) in the earlier years. However, in the University of Virginia's landscape architecture master's program Brian Osborn introduces a rule-based approach to topographic form generation as part of the very first foundational studio.[70] In this studio, students begin with investigations of the characteristics and meaning of common landform typologies such as the hill, valley, ridge, cave, swale, scarp and hoist. Students explore how these physical forms are influenced by factors and processes including geology, geomorphology, hydrology, erosion and vegetation, along with investigations of their spiritual and symbolic significance. This work is presented through topographic plans, sections, laser cut models as well as written cultural analysis. The second phase requires the application of the knowledge or 'rules' gained from students' typological studies, considered through procedural (another term for parametric) modelling, using the Grasshopper plug-in with Rhino (Figure 1.15). Students are encouraged 'to play' through the choreographing or scripting of new landforms that respond to the rules that they have uncovered. In the final stage, students use CNC milling to produce a 3D model which is used as a mould to cast final models.

Returning to earlier definitions of a parametric approach to design, we can see how this sequence of exercises explores the 'transformational behaviour' of land form, moving from the conceptualisation of shape (for example hill or valley) into an understanding of the rules which establish these topographic formations. Osborn considers a rule-based approach to topographic form a highly relevant development for landscape architecture, establishing links between form, forces and performance. He states:

> Digital techniques prompt a shift from the modelling of form to the modelling of behaviours and interactions – where landscape form is the iterative mixing of material tendencies and variable design inputs. In the context of teaching, I like that this prioritises a rule-based approach to design and one that is dependent on the interaction between form and the forces acting on it. Digital techniques encourage students to think of the landscape in if/then conditionals. If wind gusts from this direction, then debris and sediment will accumulate in this way. Because we can also think of the landscape, and ecology, in terms of sets of behaviours and interactions, parametric software becomes an ideal tool for working with landscape media.[71]

How then does an emphasis on formation rather than composition manifest in a complex design process for a built work, which requires an engagement with multiple, and at times conflicting, design parameters? Australian firm ASPECT Studios' design approach for the *Victorian Desalination Project* demonstrates the merit of a parametric process in the development of one of the largest and most complex infrastructural works in Australia.

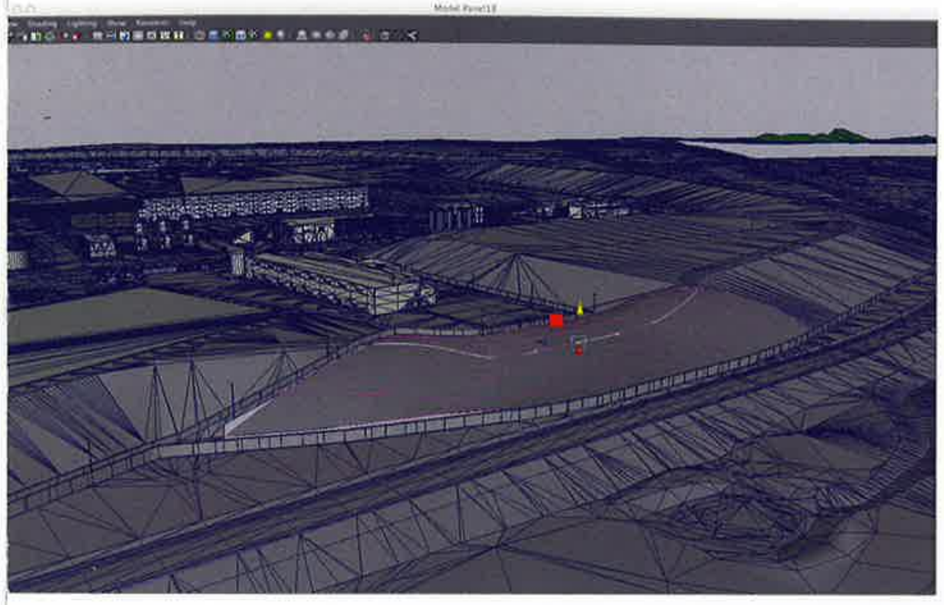
Conceptual parametrics

The *Victorian Desalination Project* was conceived as a public service to provide a secure water supply to the Melbourne metropolitan region in response to climate uncertainty and challenges of decreasing precipitation. It was designed to produce up to 150 gigalitres (GL) of water a year, with the potential to extend to 200 GL. At the time of its design, it was considered the 'largest public sector investment in water infrastructure in Australia' and 'the world's largest Public Private Partnership (PPP)' with a contracted capital cost of AU$3.5 billion in 2009.[72]

Constructed in a scenic coastal environment in south-eastern Australia (Figure 1.16), popular with tourists, development of the desalination plant resulted in debate concerning its scale and cost. To diminish the environmental impact, the competitive tender process included strict evaluation criteria, including the

1.16
The *Victorian Desalination Project* was envisaged as a 'green and climate change conscious' infrastructural project that includes extensive revegetation in the 225 hectare coastal park and construction of the largest green roof in the southern hemisphere.

1.17
The Maya model operated within engineering, architectural, and landscape constraints and allowed the designers to manage what the landscape architects described as the 'tyranny of scale'.



1.18a–c
Testing iterations. The relationship between architectural infrastructure, landform and visual experience was tested from selected geo-referenced locations up to 10km away. The aim was to reveal at certain locations the green roof of the architecture (and not the infrastructural plant) without compromising the visual and spatial integrity of the topography.

mitigation of visual intrusion and noise; protection of the coastal and marine environment and the recreational values of the adjacent coastal reserve; and the maintenance of 'the highest level of health, safety and aesthetics throughout the delivery and operation of the Project'.[73]

The integration of the infrastructure with the surrounding landscape, including a vast infrastructural plant measuring over 20,000 square metres, was central to the success of the winning bid led by an international consortium of engineers and architects, including the Melbourne-based landscape architects ASPECT Studios. Within this process, the visual impact of the scheme did not form the dominant design parameter, instead offering just one of many criteria that the designers responded to. Unlike many design approaches that seek to visually hide or mask the presence of infrastructure within visually and ecological sensitive sites, this project aims to integrate the project within this unique environment by extending the dunal landscape and conceiving the site as a landscape experience. Thus, the topographic form of the *Victorian Desalination Project* is conceived by the designers as a spatial experience in its own right, emerging as 'playful and really interesting ... not just a boring and pragmatic thing'.[74]

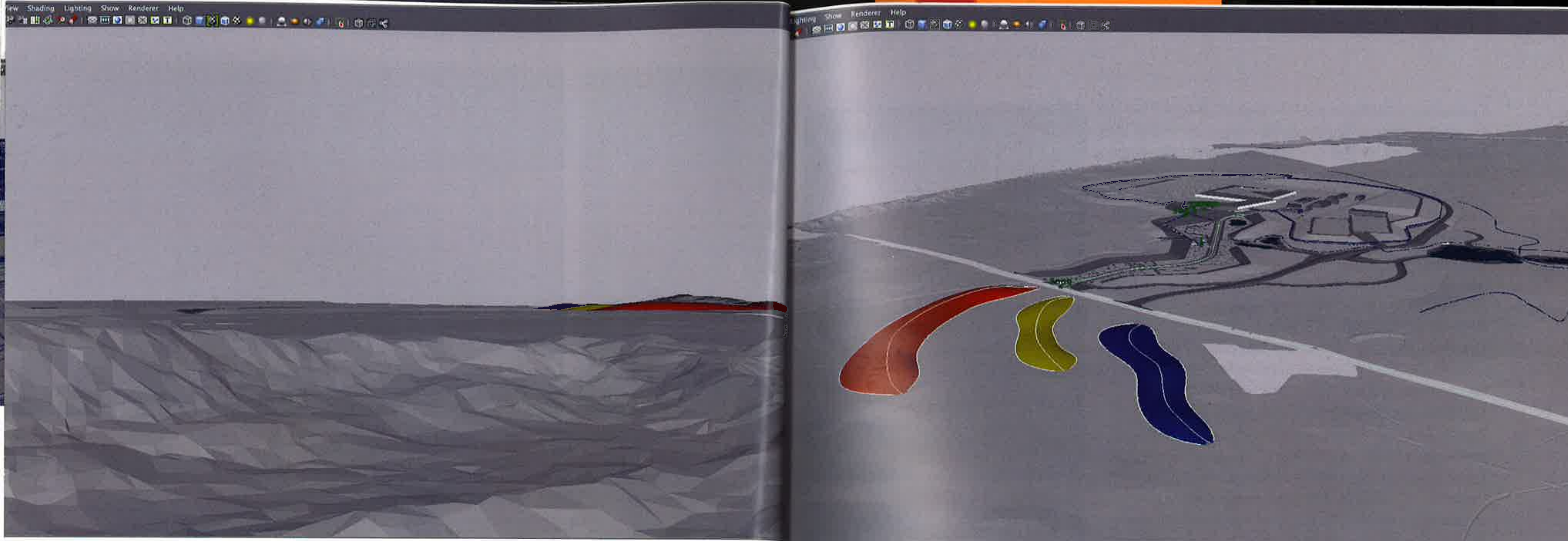
ASPECT Studios played a pivotal role in negotiating the integration of the architectural and engineering agendas with the complexity of existing topography, ecology, drainage lines and visual implications. Developing their own 3D model in Maya (Figure 1.18) based on terrain information provided by the civil engineers, offered the essential overview for understanding how all of the components related to each other. As will be discussed in more detail in Chapter 5, this model was the only representation that could communicate the entirety of the project to the client, and also informed the development of BIM documentation.

As a parametric software, Maya provides history-based modelling which includes the precise recording of command history. This permits the designer to

set and change parameters within a non-linear design process to quickly work through multiple iterations with real-time feedback. As already discussed in relation to LAAC's design for *Landhausplatz*, Maya's polygon surfacing tools offers the designers fast generative modelling of topographic form. The software's origin in the animation and film industry introduces other useful digital tools, including the setting up of animations to document the development and experience of design iterations. The designer's intent to develop a multifunctional landscape, combined with the versatility of Maya software led to a design process that mixes intuitive exploration of form with a rule based design approach which we define as a 'conceptual' example of parametric modelling.

In detail, ASPECT Studios were working with two defining constraints: first, the navigation of the visual experience and blending of the infrastructure with surrounding conditions from set locations, defined by the client. And, second, a careful management of cut-and-fill volumes, which the engineering firm, as lead consultants, had committed to during the tender phase and which was considered essential to maintain from a cost control perspective.[75]

Importantly, the model allowed the designers to work concurrently across multiple scales; testing the impact of their proposals from accurately located GPS points, while also understanding the experience of space at a more immediate level. The landscape model provided the ability to interrogate the intersection of the architectural form and the surrounding topography to a high level of detail. Within conventional representational methods which rely on multiple sections and 2D contours, these 'very fine movements' would be extremely difficult to comprehend.[76] The screen shots shown in Figure 1.18 highlight the advantages of the Maya model to the designer in visualising and understanding the complex relationship between architecture, infrastructure and landform. Working side by



1.19a–b
Balancing the extensive cut and fill generated by the infrastructure was a critical design parameter. The engineers provided calculations of fill, recommended locations for earth mounds, together with prescribed heights (and at times side profiles) to which the landscape architects responded. The landscape architects could still move the tops and crown lines to explore different configurations in line with design criteria. The proposed dunal forms in this scene are designed to blend into one continuous dune and are colour coded to test their form and alignment from a range of scales and perspectives.

side, architects and landscape architects could design directly within the landscape model, understanding in real time the ramifications of design decisions.

The Maya model proved invaluable in developing an iterative work flow, allowing the designers to work through multiple possibilities while simultaneously understanding the implications of their design on cut-and-fill volumes. Parametric drivers (such as gradient and slope sequence) were established on top of the rough mounds provided by the civil engineers. Form could then be manipulated and tested through the pushing and pulling of points. For example a tool extension scripted in Maya's embedded language MEL, provided immediate visual clues whenever slope gradients exceeded the set values. An additional command established in Maya permitted the landscape architects to run 'cubic metre volume calculations' alongside their topographic modelling explorations.[77] While not calculated in real time, this process, states designer Jesse Sago, 'was as close as possible to obtaining a real time review with the existing technology'.[78]

Revisiting Osborn's earlier quote on 'if/then conditions' which emphasises landscape form as the iterative mixing of material tendencies and variable design inputs, we can see that through the introduction of parametric components into the modelling process, the designers could develop more complexity and accuracy in conceiving the experience and performance of the topography. This modelling process provided ASPECT Studios with enormous confidence in responding to the parameters established by the engineers, in addition to the ability 'to spit out fast visualisations to the people who had to approve their work'.[79] Most importantly, it provided the landscape architects with a detailed understanding of what they had produced, 'as every bit has a purpose worked out in 3D'.[80] The ability to understand and manipulate the intent of the topographic landform fundamentally shifts the landscape architect's position within a large-scale infrastructural project. The landscape architects are now integral to the design itself, no longer limited to screening infrastructure (predominantly through vegetation) after all the major design decisions are completed.

The design process also offers a very different mode of interactivity between the designer and the media to that experienced in 'paper-based' interactions. Whereas a designer interacts directly with the shapes and forms drawn on paper, within a digital design process the designer 'interacts with, controls and moderates generative and performative processes and mechanisms'.[81] As the landscape architects observe, this process 'fundamentally changes the way that designers play with the forms they are working with shifting the way they see them, experience them and think about them'.[82]

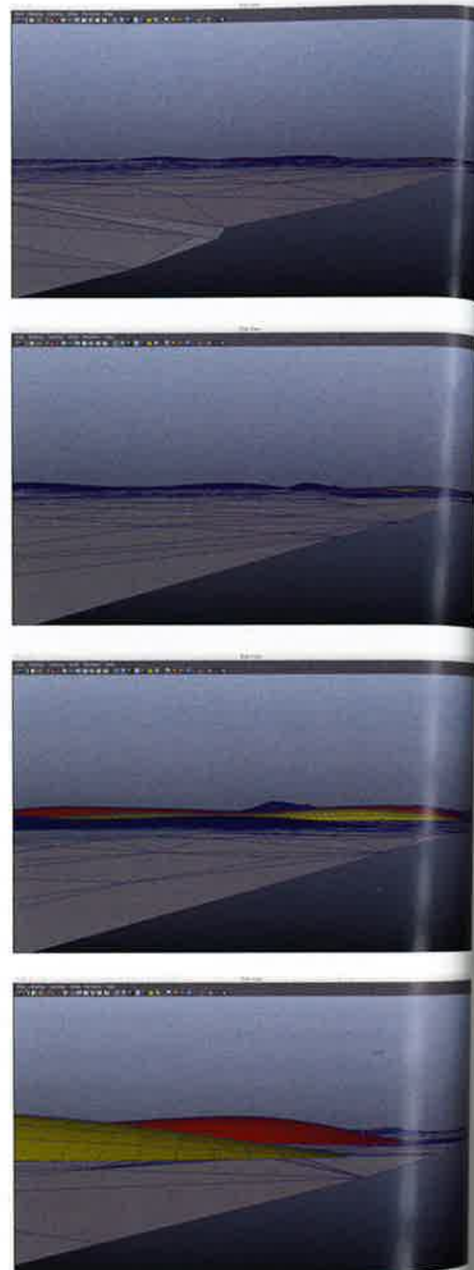
In the following section we continue the discussion of the potential of parametric modelling to the design of topography through an examination of Snøhetta's scheme for *MAX Lab IV* in Sweden. As we established earlier, there are very few examples of constructed landscape architecture projects that have been generated through parametric modelling. Snøhetta identified that the particular challenges presented by the *MAX Lab IV* project – the use of topographic manipulation as a design strategy to support the dispersal of surface vibrations – offered the perfect opportunity to explore a rules-based design approach. The *MAX Lab IV* project therefore forms an extremely important precedent in understanding an emerging digital design practice of landscape architecture and consequently we offer a detailed analysis of their design process and reflections.

Rule-based parametrics

The MAX (Microtron Accelerator for X-Rays) Lab IV is a new facility for synchrotron radiation-based research at the University of Lund in southern Sweden. The project is developed in collaboration between the University and the Swedish Research Council and upon completion in 2015 will provide the brightest source of synchrotron light in the world. Constructed on a 19 hectare greenfield site just north-east of Lund, the lab consists of two storage rings, a linear accelerator, office buildings and surrounding landscape. In order to achieve the precision and high quality of light in the synchrotron, one of the major challenges of this project was to create a stable atmospheric environment that controls vibrations, temperature and humidity.

The design of this highly specialised facility began with a design competition in 2010 that asked four shortlisted entrants (3xN, FOJAB, Grimshaw and Snøhetta) to develop design schemes for both the architecture and landscape. The project was given to the Swedish architects FOJAB who commenced design development by the end of 2010. But while each of the shortlisted teams addressed both the architectural and landscape requirements, the jury remained undecided on the winner and eventually invited Snøhetta landscape architects to collaborate with FOJAB architects (although without a clear agenda on how the two offices would work together at such a late stage). When Snøhetta started their designs in January 2011, it was already decided that construction would commence in April, leaving them only 4 months to develop their design from concept to construction. For a project of such high stakes, this constitutes a remarkable and challenging condition in regard to collaboration and the incorporation of necessary specialised expertise.

Both teams considered it unfeasible to simply merge the two competition entries together, leading Snøhetta to establish a new design approach to the



1.20
Screen shots from an animation used to test the experience of the proposed dunes for the *Victorian Desalination Plant* (from the road).

landscape. While the team originally started the new design with conventional landscape architectural considerations such as balancing cut-and-fill volumes and storm water management it soon became clear that the mitigation of surface vibration that had been discovered and researched in detail only a year before the project started, would provide the most valuable constraint to push the design forward into new territories.

Working with sensitive equipment and procedures that require utmost stability in atmospheric and spatial conditions, it was feared that the nearby motorway E22, located fewer than 100 metres to the west of the site, and a local road to the east, could negatively interfere with the magnets in the storage rings and the beamlines. Simulations had demonstrated that very small irregularities in the road's surface produced by twigs, stones and ice had the potential to disrupt the workings of the facility.[83] In addition to these hard-to-control external factors 'new emerging technical possibilities' would place further demands on the facility in regard to the accepted tolerance in atmospheric interferences.[84] Needless to say, the architecture would contribute a major role in controlling the vibrations through various material and construction techniques in a manner that would conceive that 'the building is a part of the machine'.[85] But there were unavoidable challenges and limitations as to what the architecture could achieve as the Detail Design Report outlined:

> Isolating buildings from external vibrations could be quite demanding, considering the wavelength of the low-frequency vibrations. Isolating floor from roof and outer walls is, however, a relatively simple means. Damping of the floor could in fact be contra-productive. Damping materials are weak and thus might increase vibrations in the low-frequency part of the spectrum, which is responsible for the major contribution of the displacements.[86]

In addition, the lack of terrain movement in the slightly sloped agricultural landscape so typical for Sweden's southernmost province Skåne was seen to potentially further extrapolate and distribute the vibrations. While the constraint caused severe concerns for the client, they became the major source of inspiration for the landscape architects, leading designer Jenny B. Osuldsen to reflect on the discovery of the vibration issue with great enthusiasm, stating 'This is so interesting! This is a fantastic parameter we can work with.'[87] It became clear that the landscape design required a rule-based design approach, reframing constraints into opportunities to inform and drive design explorations. Osuldsen comments 'Even though I had no idea how this process would look like I knew it was really essential to work in 3D and parametrically.'[88]

Here we see clearly the value of digital technologies in inspiring a fundamental shift in design culture, both theoretically and practically, encouraging the designer to explore the creative opportunities immanent in constraint-based modelling. The vibrations properties defined parameters that could translate into spatial definitions, such as length, location, orientation and direction and offered a rational for the form making and mass balancing (Figure 1.21). The designers began by establishing a grid of points (using Rhino and the plug-in Grasshopper) on the site. This grid was applied on a smoothed terrain surface that maintained the existing curvature of the site which stretched from the higher points in the centre, where the storage ring is situated, through to the lower lying roads on both sides. This allowed the designers at a later stage to consider the intersections between the new landform and the existing uneven topography. While the wave lengths were defined as a fixed parameter, their orientation, location, direction, amplitude, frequency and slope gradient could be varied and tested through adjusting the input units and mathematical functions in the parametric model.

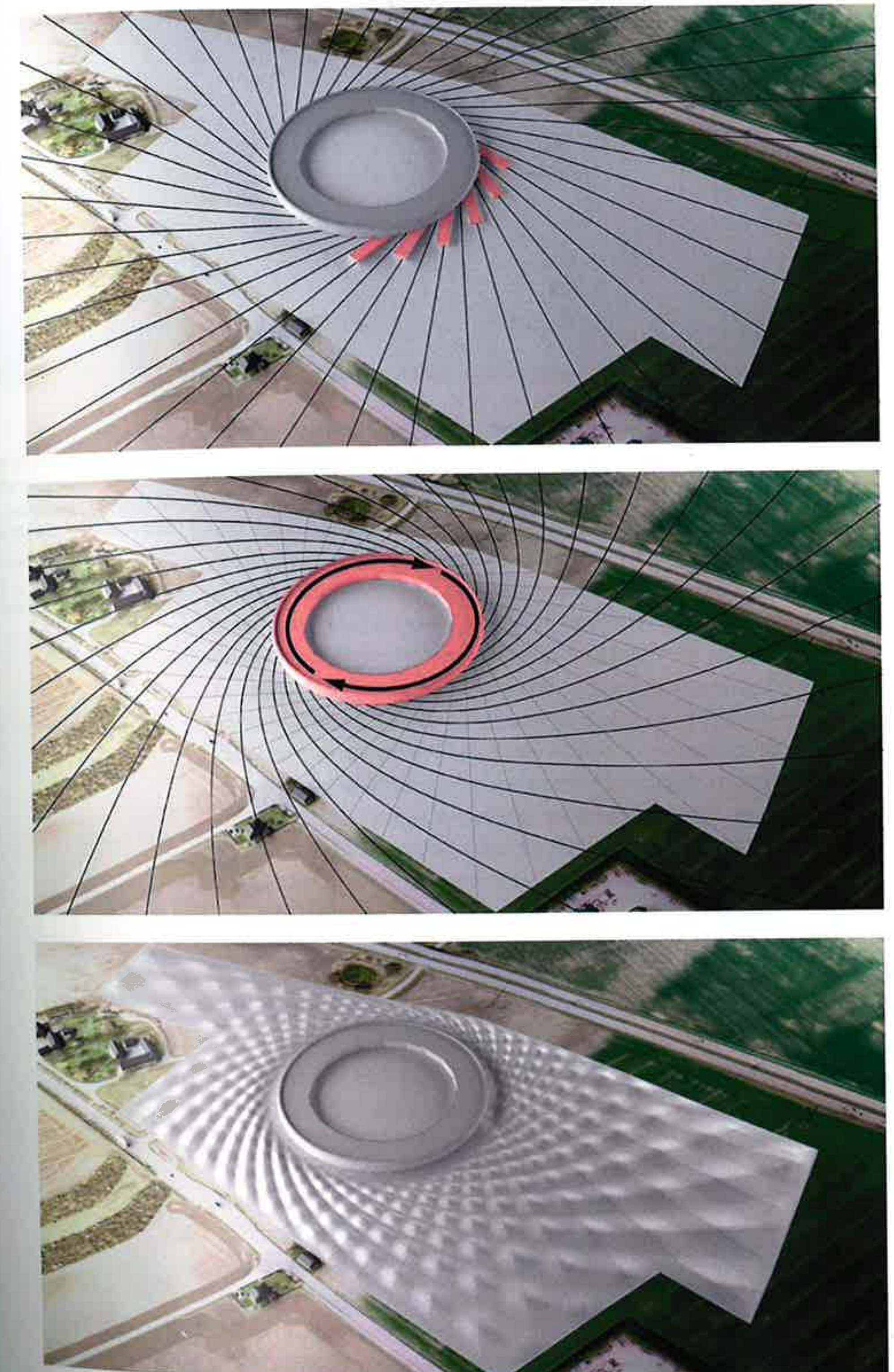
The alignment of twenty tangents with the circular form of the synchrotron that would emulate the movement of the electrons in the storage ring and the light in the beamlines formed the starting point for the new topography. Waves were then added along these tangents to scatter the surface vibration, starting with a length of 10 metres closer to the facility and extending beyond 40 metres by the end of each tangent. Early experimentations began as a creative endeavour but with increasing refinement and understanding of relational attributes, additional constraints could be scripted into the model for more control and feedback.

Testing the design

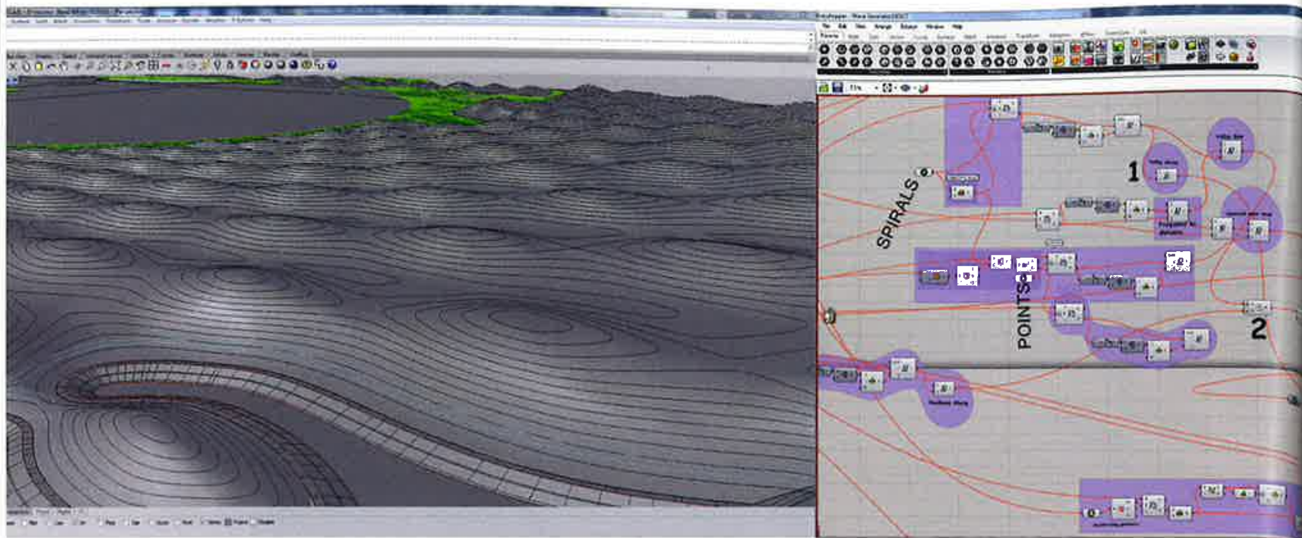
The construction of the 4 metre deep floor slaps indented to stabilise the soil beneath the two storage rings (the largest 528 metres in circumference and the smallest 96 metres) required extensive earth excavation that was then available to construct the undulating landscape. Working with the 3D model facilitated close collaboration with the engineers in Lund to review the balancing of mass volumes. Their recommendation further refined design considerations, such as identifying the optimum wave amplitude at a maximum 4.5 metres to achieve the overall mass balance.

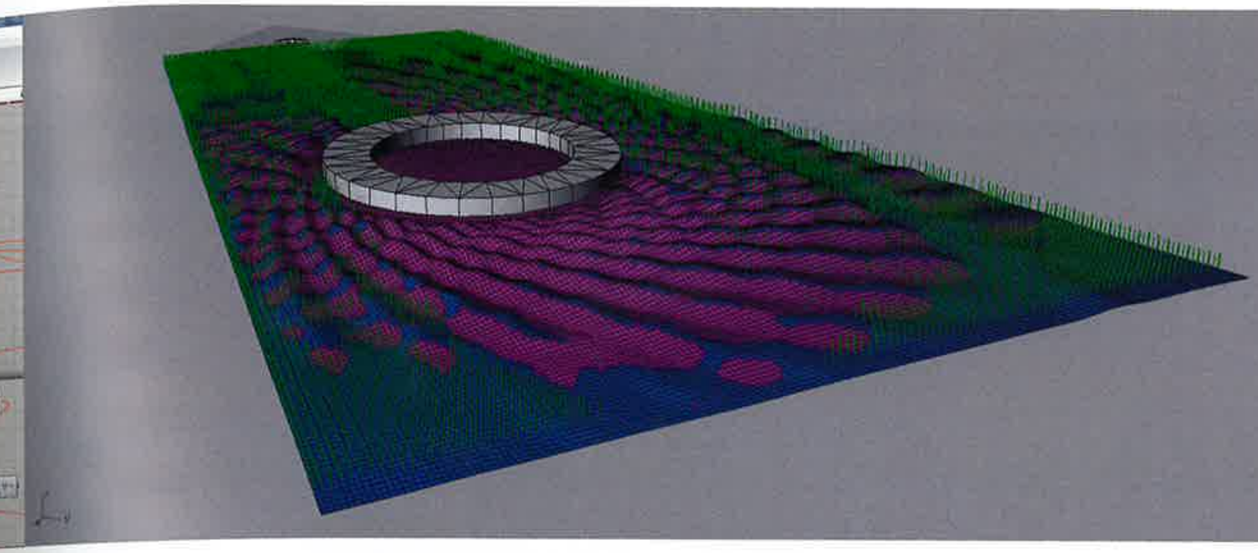
Parametric modelling allowed the designers to rigorously test and control their topographic explorations. Using Grasshopper, a series of small definitions (another term for script or code) were developed to test the performance and experience of the emerging topography. One definition established a slope gradient to a maximum of 1:4 (determined as the steepest possible grade for maintenance and an effective grade for managing storm water run-off). When applied to the model, the definition introduces changes of colour whenever the slopes exceeded the set gradient parameter, providing Snøhetta evidence of their form and decision-making process.

Other definitions aided the resolution of proposed and existing site conditions without compromising either the strong geometry of the design or the site context. This was particularly valuable for resolving the edge conditions, maintaining



1.21
Beginning with the premise that the impact of vibrations could be reduced through the addition of terrain movement and the maximisation of the land surface through a waved topography, the design process started with the exploration of long waves between 10 and 40 metres radiating out from the synchrotron. This length was defined by the researchers as the most problematic for the smooth operation of the facility, adding more chaos through reverse waves and formation of topography.





existing trees and inserting the plazas and roads into the design. The environmental performance of the design was tested using Kangaroo, a live physics engine plug-in (that operates in Grasshopper) that visualises physical behaviours in the modelling environment through particle simulation flow.

In earlier models which featured only one set of tangents, the animation highlighted where landforms would create dams, and revealed difficulties in guiding water towards the constructed wetlands. A definition was also developed to test how the topographic form interacted with the major wind conditions of this exposed site. The resulting model (Figure 1.23) highlighted where the topography created wind shadows and was used to inform the location of tree planting. Through additional definitions the designers could have explored the relationship between planting design and wind modulation in more detail. However, the quantity of trees necessary to achieve an effective windbreak was not acceptable for the client, requiring Snøhetta to dramatically reduce the number of trees. Thus, despite wind being a crucial factor in Skåne for most of the year this exploration was not pursued further.

The topographic form therefore evolved constantly through the testing of variations engaging with parameters such as vibration dispersal, drainage, wind and slope. The digital model was regularly sent to the engineers to test and validate the design against the vibration patterns and to provide feedback on how the landforms could further increase dispersal performance. Simulations suggested that a series of parameters, such as larger sized hills applied at an angle; smooth, rolling landforms composed of both hills and valleys; and finer patterns would achieve higher quality outcomes regarding the displacement of vibrations.[89] Since previous research had demonstrated that the more chaos added to the surface, the better the scattering of the vibrations, it was decided to add a second set of tangents intersecting with the first set, to create more surface variations (Figure 1.24a).

The application of two similar sets of tangents, as recommended by the engineers, produced a rigid landform that could not accommodate run-off. This then inspired the application of a twisting second set of waves to create more

1.22a–b
Testing the water run-off from the proposed topography using a Grasshopper definition to highlight areas of poor drainage.

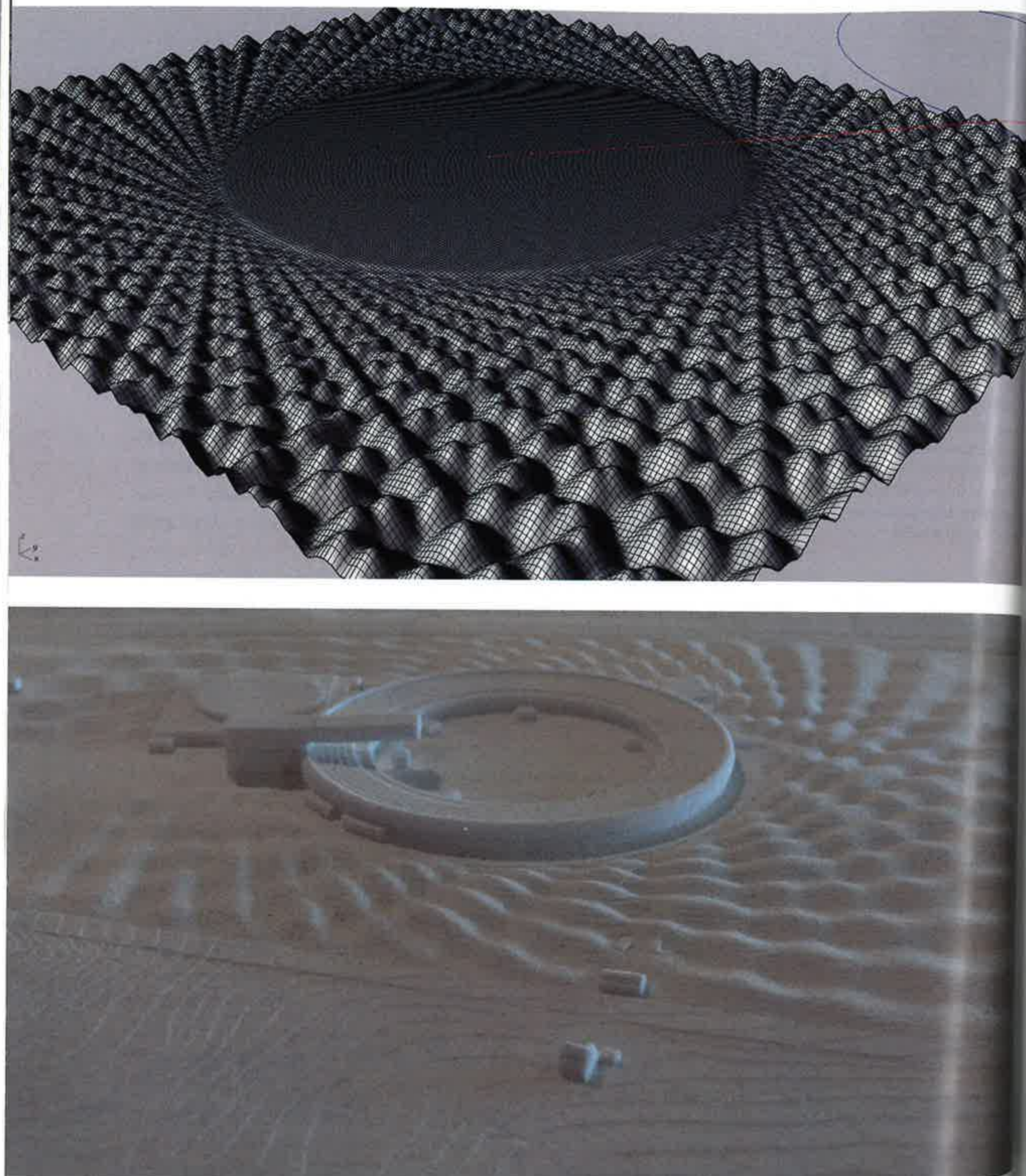
1.23
Working with Grasshopper to test the topographic form's interaction with the wind conditions. The surface colour of the model changes depending on exposure to certain wind speeds.

flexible spiral shaped surfaces which formed the final topographic form. During this parametric design process, Snøhetta navigated a balance between developing sufficient surface undulation to address vibration performance, while maintaining other important qualities such as maintenance, ecological considerations, micro-climatic factors and the user's perception of the designed landform. For example in some moments the designers elected to not perfectly drain the site, instead encouraging the water to pool to create evocative ephemeral ecosystems.

The interrogation of the user experience of the proposed landscape can be achieved in many formats, for example as discussed earlier ASPECT Studios utilised digital animations as a preferred tool to visualise and explore the landform for the Desalination Plant. In contrast, Snøhetta drew on printed 3D models, which became an essential communication and decision-making tool. Test models at 1:2000 scale were printed for weekly client meetings to check even the slightest changes in patterns, wave amplitudes and surface intersections (Figure 1.24b). More detail models at 1:200 accompanied these larger scale models to further visualise and test the intricacies of the curvature. Snøhetta also kept a second set of printed models as a record of their design explorations and decision-making process.

As discussed earlier in this chapter, the use of physical modelling in the exploration and testing phase of design has not been a feature of landscape architecture design. The availability of CNC routing and 3D printing which favour the representations of the slope and smooth surfaces, paired with a rapid production time, make physical models more relevant to the landscape architectural design process. As Osuldsen reflects:

> I don't think that we would have ever been able to achieve that [the weekly models] if it was not based on a 3D model that we could plot because it is now so fast to plot it. So you can test, and run models, and change it again in a really fast way. The site is large and if we should produce that in an old-fashioned cardboard model, I don't think we would have tested the idea because it would be too hard.[90]



1.24a–b
Digital model testing a more chaotic landform. 3D printed models formed an important tool for the design exploration, communication with the client and an important record of the design process.

New design processes

For Snøhetta, the *MAX Lab IV* became an important exploration in the possibilities of parametric modelling in landscape architectural projects both as an intellectual and practical endeavour. Their experience highlights an extremely flexible modelling process where designers can respond quickly to new information, qualities and observations. Consequently, the designer becomes less precious with their ideas and open to new explorations. As Pål Hasselberg, an architect involved in the *MAX Lab IV* comments 'You don't think about it. You just try to do it.'[91] Without this approach, changes to the large-scale complex landform manipulation of *MAX Lab IV* would have been extremely time-consuming, leading to less exploration and experimentation in form generation.

Snøhetta's experience also highlights the new conceptual demands that parametric modelling places on designers as they depart from linear segmented workflows into non-linear design processes. It could be assumed that a rule-based or a procedural approach to design is accompanied by a clear linearity of operation. This process however must be controlled by the designer (as distinct from the assumption that the computer generates the design). As Branko Kolarevic commented earlier, 'The designer essentially becomes an editor of the generative potentiality of the designed system, where the choice of emergent forms is driven largely by the designer's aesthetic and plastic sensibilities.'[92] Hence the designer must now operate in a far more explicit and formal manner than what is commonly associated with more traditional models of design processes.[93] We discuss the differences in these design processes in far more detail in Chapter 2.

The ever expanding potential of software, combined with the increased capability of the designer to code, places more importance on understanding workflow and efficiencies. For instance Snøhetta could have developed a script to receive real-time feedback on cut-and-fill balance. Instead, they adopted a more intuitive exploration guided by defined parameters and responding to the mass calculations provided by the engineers. To engage with real-time feedback was as much a liability concern, as it was a workflow consideration, since it would require multiple scripts to run simultaneously. Pål Hasselberg, comments 'you could put everything into one magical script but that would become so complex that sometimes it's hard to work with, because it is calculating everything at the same time'.[94] The more factors added to the script, the more complex the modelling process, as each parameter has to be managed to 'make sure that they don't interfere with one another'.[95] Thus, in some cases it may be more valuable to work on one parameter at a time. This requires the designer to understand and to control modelling processes to ensure it works best for design intent.

In the future, other research laboratories such the ESS (European Spallation Source) further to the north will join *MAX Lab IV* to form a new Science City to provide world-class facilities in scientific research and innovation in Lund. In light of the growth plans and the international significance of the developments in the region, the *MAX Lab IV* was conceived to 'be an eye catcher' in the landscape.[96] As

1.25a–b
MAX Lab IV under construction (2014) and a rendered view of the final design proposal including the wetlands in the foreground.

1.26a–b
Experiencing the undulating wave landscape during snow and a rendered summer view. Figure (a) also shows the integration of existing and new planting within the landform system.

shown in Figures 1.25 and 1.26, this was achieved. Osuldsen comments that while in a programmatic sense the design of *MAX Lab IV* was 'not at all what the client was asking for', the landscape design now forms 'an iconic part of the project – not just visually but also functionally'. Thus the opportunity of a rule-based design really lies in detecting a significant parameter and to use this as leverage to 'lift landscape off just the practical stuff'.[97]

The parametric process therefore offered Snøhetta more possibilities to advance their relevance in projects where clients have only a marginal understanding of landscape performance. As Osuldsen states in many of their projects clients only require the most basic deliverables.[98] In the case of *MAX Lab IV*, the parametric modelling process, combined with new technologies such as 3D printing, empowered Snøhetta to expand the complexity of their design, while also offering clear demonstration to the client of the systemic, performative and experiential qualities of the final design.

Conclusion

Many of the concepts introduced in this chapter such as parametric modelling and scripting may still remain confusing and foreign to some readers. To engage with the potential of digital technologies is to understand a new language, new workflows, design processes and theory. This understanding will continue to develop over the course of the book as we expand on these major concepts and developments in more detail. The most critical knowledge to take from this chapter is the understanding that design logic, knowledge and processes change with computational design, and that the digital model is core to this revision.

The topographically driven design examples discussed in this chapter present four different roles for the 3D model in the design process. In their design of *Landhausplatz*, LAAC worked directly with their 3D model to digitally sculpt precise and novel landforms that responded to very specific conditions and constraints inherent in the site. In contrast PARKKIM in their design for *Mud Infrastructure*, generated an initial design concept in plan which was then explored, tested and refined within a 3D model. In these examples, the designers explore form through 'tool-like' operation which modifies space in real time onscreen. Surfaces are modelled intuitively, with the algorithmic formulae remaining embedded within the software, and as a consequence the designers are not actively applying a rule-based design approach.

In the later examples we see a major change in design logic and in the role of the design model. Emphasis is now placed on the 'design' of the model which becomes the primary space of exploration and generation. Working with the versatility of Maya software, ASPECT Studios' design process mixes more intuitive exploration of form with a rule-based design approach, including the testing of very

particular parameters such as slope gradients. We define this hybrid of techniques as a 'conceptual' example of parametric modelling.

The final example of Snøhetta's approach to the design of *MAX Lab IV* offers a far more explicit application of rules, encouraged by the design brief which required the topographic form to disperse surface vibrations. The vibrational properties provided a clear parameter that could translate into spatial definitions (such as length, location and orientation) offering the foundations for developing a topographic form. The performance of this emerging topography was iteratively tested against criteria ranging from drainage, wind and slope gradients to its ability to minimise vibrations, using a mix of bespoke scripts and open source plug-ins. Importantly, the designer requires a far more precise design thinking than what is commonly associated with more traditional design processes, explicitly curating the generational potential of the parametric model.

In the following chapter, we continue a focus on parametric modelling and performance, with a closer interrogation of its value to a contemporary design of practice of landscape architecture.