图01 奥林匹克公园和湿地鸟瞰图
Fig.01 Aerial image of the Olympic Park and wetlands
图02 阿特金斯为公园提供河岸修复工程技术
Fig.02 Atkins provided river edge engineering on the Park
图03 实验证明用椰壳纤维来培植物是最好的选择
Fig.03 Trials proved that planting in coir matting would be best

伦敦2012奥林匹克公园滨水景观设计与营造

Riverfront Landscape Design for London 2012 Olympic Park

如果在不久的未来，将有数百万人途经这块滨水区域，沿河该如何种植？如果了解到自然界中人造湿林地已十分罕见，该如何设计、创造并维护周边这种湿地环境？该如何长期保持栖息地的活力和可持续性？在伦敦2012奥林匹克公园项目中，来自阿特金斯的工程师们受托负责湿地和河滨地区设计及建设，将会找到所有这些问题的答案。

为2012年伦敦奥运会和残奥会而新建的奥林匹克公园是由一片废弃工业用地改造而成，占地超过246hm^2，是欧洲最大的城市景观项目之一。东伦敦下利亚山谷的河流和湿地形成新的风景将是整个新公园的视觉中心，并为2012年伦敦奥运会平添景色。

阿特金斯负责河岸和湿地的软化设计，以及河岸修复和生物工程。从项目的概念设计到施工建成，阿特金斯的工程师们发挥了重要作用。该项目不仅仅修复了超过8km长的河岸，同时还修建了2hm^{2}的芦苇地和池塘和9000m^{2}的珍稀湿林地。这样的河岸改造力度可谓史无前例（图01）。

项目的挑战在于要使人们从观、行两方面都能有更好的亲水体验，因此设计要让河流更具可达性和开放性，并由此成为公园的焦点景观。

迈克·沃恩领导了阿特金斯的多学科设计团队，其中包括河流工程师、地貌学家和生态学家。“我们希望通过调整陡峭的斜坡来打开河流廊道，”迈克解释，“坡度降低后，河水被引入公园，也更具可达性。人们可以近距离靠近河边，观察这里到底发生了什么。”

精确的河堤几何处理是一门微妙的平衡艺术。河堤若太陡，河岸的人工加固成本将高居不下；河堤若太浅，河流会开始侵蚀场地上宝贵的空间。最终设计采用的坡度为1:2.5，约为22°。河堤的占地空间则受限于疏导洪水、陆地景观和基础设施的需要。因此，对于过度陡峭的河堤采用了两种办法：第一，尽可能地用椰皮纤维卷和木桩沿斜坡堆垒河提；对于一些坡度达70°的河堤部分则采用加固手段，设计了多层土工格栅和钢丝网笼，表面覆以草皮。

如今，新的景观正在迅速成型，利亚山谷的旧貌已难觅踪迹。在2006年伦敦奥运交付

管理局拿到这块土地之前，这里的河道纵横交错，被入侵的杂草所阻塞，还有旧购物车和汽车轮胎等城市废弃物被随处丢弃。

利亚山谷中没有被好好照管的河道网络不仅仅是城市的“眼中钉”，更成为了“绊脚石”——它将西面的哈克尼区（Hackney）和陶尔哈姆莱茨区（Tower Hamlets）与东面的沃尔瑟姆福雷斯特区（Waltham Forest）和纽汉区（Newham）分而隔之。

现在，重新焕发生命的水路以及横跨其间的新交叉点，不论在赛期还是2012年之后都将十分重要。它们是遗赛后规划方案的一个主要部分，将新公园及其水网与东伦敦大范围内的规划布局连接起来。

1 栖息地再焕生机

伦敦奥运交付管理局对奥林匹克公园夯子厚望，希望场地中大部分河流和自然特征都能创造可持续的栖息地。但是要将杂草和垃圾填塞的河谷转变为其最初的原始状态，是一个漫长而艰难的过程。

阿特金斯的工程师们先深入了解场地上盘枝错节的河道水路，并在一定时间内对不同地点的水流量和水速进行监测，将收集的数据构建了一个精细的水力模型，用以预测洪水风险。这点极其重要。因为阿特金斯承担着场地上平均海面（海平面）4m以内的所有责任。

在环境影响评估阶段，洪水风险的充分评估就已展开。分析不仅包括了由于频繁降雨造成的雨洪，还考虑了由于潮汐变化和蓄水所造成的水位自动调节。2008年期间，河道系统进行了蓄水，使得建模过程相当复杂。实际上，尽管蓄水削弱了潮汐对泰晤士河的直接影响，但间接影响仍然存在。“当潮汐来临，它会阻碍河水排出李河。”迈克·沃恩解释，“因此，水位一天的变化能达到平均400mm。”

阿特金斯的模型计算准确地预测到了这一现象，以及由此增加的洪水风险。“这些发现带来了景观轮廓上的改变。”迈克说，“沿河道路被抬高了1m，同时对湿地的轮廓也做了抬升。对于它们的生存而言，保持正确的水位十分关键。”

公园大量运用了可持续的排水技术。在景观领域，广场采用了渗水性材料，水可流入与河边池塘相连的生态洼地。此外，还采用了地面运输、地下管道和存贮等多种手段（图02）。

由于原有的河堤许多部分非常陡峭，因此河道修复的第一步就是让河堤“躺下来”。经过几个世纪不断地堆积，有的地方地平面高达10m，堆在河堤上的垃圾有碎石、玻璃、动物骨头和更近一些时期从伦敦最东端运来的拆除的战时物品。

项目面临的另一个挑战是遍地的入侵植物，如喜玛拉雅凤仙、日本紫菀和巨猪草。这些都是19世纪由于园艺好奇心而引进英国的速生植物，却成失误之举。

入侵植物对于河堤是个坏消息。它们疯狂地繁殖、生长，驱逐本地植物，并且非常顽固。紫菀能在水泥中扎根；巨猪草含有呋喃香豆素和见阳光激活的毒素，会导致皮肤溃疡。因此清理成了优先考虑的工作——整个场地的土壤都做了处理，河堤上的所有植物被尽数铲除。

同时，阿特金斯还要保护地块上的动植物种群。2006年环境影响评估中即开展了第一阶段的栖息地调查工作，包括鸟类和鱼类的调查。同时，已着手进行了一项主要的物种迁移工作，规划了一批适宜的迁移地，包括临近公园营建的1hm²栖息地。阿特金斯迁移了330种普通蜥蜴、100种蟾蜍和4 000种欧洲滑螈。为了保护场地上的植物群，阿特金斯延续了“清除许可制”系统的做法，并详细规划了包括梧桐树林在内的多处免干扰栖息地地区。

2 选择栽种植物

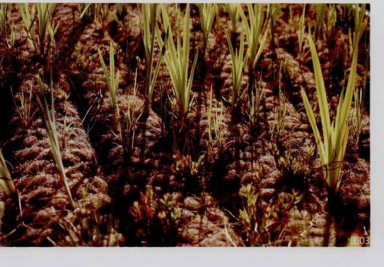
阿特金斯承担着营造河堤和湿地最终景观的任务，因此需要决定场地种植的植物种类。面对清理后赤露的河堤，新栽种的植物不仅要满足生态和审美要求，还需要在赛期开花——但要符合工程规律。

团队选择了生态工程技术，即用植被和自然材料而非水泥来保护和巩固河堤。那些有着良好根系的合适的植物能有效保护河堤不被侵蚀。

但河网的半潮汐状态又提出了新的挑战。水位一天之内约400mm的升降会给新种植物带来很大的潜在威胁，河流的高载沙量也会让种下的植物面临缺氧危险。“我们确实没有一个自然的河道系统，”迈克说，“植物无法适应这种生存条件。”

为了找到成活率高的植物，并且建立最有效的种植方法，阿特金斯在奥林匹克公园内李河的一段50m长的河堤进行了特殊的种植试点。

“我们尝试了不同海拔高度的植物和不同种植技术，监测观察了1年。”阿特金斯高



级环境科学家伊恩 · 莫里西（Ian Morrissey）说，“这些工作对于我们选哪些植物和在哪里种植很有帮助。”

试点显示直接插种的植物大易受到伤害，但预种在椰皮纤维垫上能避免被冲走或淹没。椰皮纤维还有一个好处——能方便又快捷（图03）。

“垫子本身可用作覆盖物，因此能阻止可能混在筑堤土料中的杂草从中生长出来。但更重要的是，当河堤泛洪被淹没时，椰皮纤维具有很好的沉积物收集作用，帮助植物根部固定和汲取营养。”伊恩说。

3 寄望明日幼苗

创造可持续性的河堤生态系统意味着采用本地物种。因此，在河堤重整以前，已经收集了一批本地水生物种的种子——这一过程由阿特金斯进行管理——并且储存在一个种子银行。部分种子由生态工程和苗圃专家组萨利克斯团队(Salix)进行研究。他们受伦敦奥运交付管理局委托离线培育植物，这也被认为是英国有史以来最大的苗圃合同之一。

这项工作的工作量非常巨大，2009年6月就开始了播种。因为在面对河堤恶劣环境之前，植物必须经过一年生长并且妥善种在椰皮纤维托盘中。

萨利克斯团队在斯温西附近的半岛苗圃，培育了7 000多盆苏草等用于湿林地的植物。他们还为这个2012项目专门在诺福克新辟了一个面积约1hm²的苗圃（图04），种植了30多万株植物，大约28个不同品种，包括莎草、芦苇和驴蹄草等。它们种在上千个椰皮纤维托盘中，等待在稍后几个月里陆续运往伦敦。

2010夏季，18 000m²的植物聚集在一起，宛若一幅巨大的拼图。为了方便物流和排序，每个托盘和卷垫都做了标记。此外，在运输过程中还需要保证它们之间留有恰当的空间，防止切割到植物的根系和根茎。工程队将它们整批提取，确保不发生上述意外。

4 白手起家的池塘和湿林地

尽管阿特金斯在“旧利亚河”的河堤上花费了大量精力，他们仍然需要考虑全新的水体问题。公园北面滨水区域的生物多样性的基础部分有赖于远离东岸的3处新三角形池塘。其中两个池塘设计在夏季干涸，形成潮湿的草洼，第三处池塘则保持水体，以便诸如睡莲、驴蹄草等植物能够繁衍（图05）。

既要避免第三处池塘干涸，又要确保它不与利亚河一起泛滥，无疑是一个难题。阿特金斯在池塘和河道之间设计了一个连接渠，便于水量的补给和排出。池塘的水量变得可控：当水位太高，水便排出至河里；当池塘快干涸时，阀门打开，河水又可回到池塘。虽然这听起来简单，但被认为是首个案例在大规模栖息地采取如此做法。

新的湿林地与提升后的河道和河堤将一起成为奥林匹克公园的亮点。它们是现在英国境内罕见的栖息地，而公园内的这些栖息地更是白手起家建设出来的。

“这些任务非常新颖，”伊恩 · 莫瑞思回忆道，“挑战来源于我们要确保湿地区域的正确水位。阿特金斯负责解决地势和渠道的问题，以及它们和河流如何相互作用。”

湿地有逐渐萎缩并至最后干涸的趋势，但通过选择正确的物种、精细的水位管理和维护，这个过程可以得到延长。

“我们推荐的莎草科品种最终入选了，因为它们十分旺盛，并能与陆生物种竞争。”伊恩说。

湿地的树种包括柳树、桤木、桦树和现在稀有的黑杨，迈克沃恩指出：“它们很受野生动物的欢迎。有大量的无脊椎动物栖息这里，还有许多鸟类在此筑巢。”不过，鸟儿们会给河堤上新种下的植物带来挑战。

“野禽飞到场地上，可能会抓伤植物，”迈克说。为了防止这类事情，阿特金斯沿新植被区设计了几百米的防护栅栏，并已于2012年春季将防护栅栏拆除（图06）。

5 终点线之外

下利亚山谷地区的转变和已近完工的新公园，无论用什么标准来衡量，它们都是卓越非凡的。奥林匹克公园的参观者——在赛时高峰期将高达每天25万人——将看到一个最绿色、最环境友好型的奥林匹克公园。

公园在2012年之后仍将发挥效益。“我们真正的困难在于把力量投入到了基础设施上，这不仅有利于赛事，更作用于将来”伦敦奥运交付管理局的约翰 · 霍普金斯说，“这里的中心有河流、有公园，将成为一个生活、工作的理想之地。不论从社会、经济还是环境上来讲，都是很棒的遗产——新的景观驱动了新的城区。”

图04 湿地植物进行了1年的离线培植
Fig.04 The wetland plants were grown for a year off site
图05 3处新修建的三角形池塘有利于生物多样性。
Fig.05 Three new triangular ponds were created to encourage biodiversity.

How do you plant along a river's edge, knowing that millions of people could be passing through the site in the near future? How do you design, create and maintain the surrounding wetlands, knowing that man-made wet woodland is very rare and transitional by nature? How do you ensure that the habitat being created remains viable and sustainable in the long-term? Atkins' engineers of the wetlands and river edges on the London 2012 Olympic Park were tasked with finding answers to all of these questions.

Covering more than 246 hectares of formerly derelict industrial land, London's new Olympic Park for the London 2012 Olympic and Paralympic Games is one of Europe's biggest-ever urban greening projects. Rivers and wetlands are at the heart of the vision for the new park, which lies in east London's Lower Lee Valley. The landscape that's now emerging will provide a backdrop for the main action of the London 2012 Games.

As river edge and wetland engineers for the project, Atkins has played a critical role in turning the vision into reality. Atkins' remit includes design of the soft river edges and wetlands, including riverbank restoration and bioengineering.

The transformation is unprecedented. More than 8km of riverbanks have been restored as part of the project; in tandem with this, 2 hectares of reed beds and ponds have been created, along with 9,000 square meters of rare wet woodland(Fig.01).

The challenge was about getting people both visual and physical access down to the river-to actually make the rivers more accessible and more open, and therefore the centerpiece of the Park.

Mike Vaughan heads up Atkins' multidisciplinary design team, which includes river engineers, geomorphologists and ecologists. "The idea was to open up the river corridor by making the steep slopes that line the river flatter," explains Mike. "By dropping the slopes, we've brought the river into the park and made it much more accessible-people can get close to the river and see what's going on there."

Getting the riverbank geometry just right was a delicate balancing act. Too steep, and the banks would need costly artificial reinforcement; too shallow, and they would start to eat into valuable space on the site. An optimum slope of 1 in 2.5-about 22 degrees-was chosen. The space occupied by river bank was restricted by the need to convey floodwater and the location of terrestrial landscape and infrastructure. As such, the banks were over-steepened using two approaches. Firstly,

where possible, the riverbanks were terraced using coir rolls and timber stakes. In other locations, where only a 70 degree bank was possible, a reinforced detail was used, providing layers of geo-grid and steel mesh cages, faced with a riverside turf.

Today, with the new landscape rapidly taking shape, it's easy to forget how the Lee Valley used to look. Until the Olympic Delivery Authority (ODA) took possession of the site in 2006, many of the river channels that criss-cross the site were clogged with invasive weeds, along with the predictable detritus of urban decay: abandoned shopping trolleys and car tires.

The Lee Valley's neglected river network wasn't only an eyesore, but also an obstacle-a gulf separating Hackney and Tower Hamlets in the west from Waltham Forest and Newham in the east.

Now, the revitalized waterways-and the new crossings spanning them-will be vital not only during the Games, but also after 2012. They are an integral part of the legacy solution, stitching the new Park and its waterways into the wider fabric of east London.

1 Bringing Habitats back to Life

Making the most of the site's rivers and natural features to create sustainable habitats is a key part of the Olympic Delivery Authority's vision for the Olympic Park. But the process of transforming the park's rivers from weed and rubbish-infested gulches into pristine watercourses has been long and tough.

For Atkins, that process started with developing an intimate understanding of the labyrinth of waterways and channels that wind their way through the site. Flows and velocities were measured at different points over a period of time, with data used to construct a detailed hydraulic model to predict flood risk. That's of critical importance, because Atkins had responsibility for everything up to a contour of 4 meters above ordnance datum (sea level) on the site.

A full flood risk assessment was undertaken at environmental impact assessment stage. Atkins undertook analyses of the risk of flooding caused by frequent rainfall, taking into account the automated regulation of water levels in the impounded reaches and the impact of tidal lockout. The modeling exercise was made considerably more complicated by the impoundment of the river system during the course of 2008; in effect, this eliminated the direct tidal influence of the Thames. But its indirect influence is still felt. "When the tide comes in on the Thames, it stops water flowing out of the River Lee," explains Mike Vaughan. "So the river levels fluctuate by an average of 400mm a day."

Atkins' modeling calculations correctly predicted this phenomenon, and also the increased risk of flooding. "These discoveries led to some changes in the landscaping profile," says Mike. "The

图06 几百米的防护栅栏用于保护新生的植物。
Fig.06 Hundreds of meters of deterrent fencing protected the new vegetation

riverside paths have been raised by up to a meter and the profile of the wetlands was also raised, as maintaining correct water levels is critical to their survival."

Sustainable drainage techniques have also been used across the Park. In the landscape areas, porous strips have been used in the concourse, feeding into bioswales which drain down into the riverside ponds. Surface conveyance, underground pipes and storage features have also been utilized(Fig.02).

The first step in the river restoration process was to "lay back" the banks, many of which were precipitously steep. This re-profiling was necessary because much of the surrounding land was "made" ground, the result of centuries of tipping that had raised the ground level by as much as 10 meters in places. The cocktail of materials on the banks included rubble, glass, animal bones and, more recently, wartime demolition materials from London's east end.

Another challenge facing the Atkins team was the prevalence of invasive weeds. These included Himalayan balsam, Japanese knotweed and giant hogweed. All are fast-growing non-native plants introduced to Britain in the 19th century as garden curiosities; all have prospered on the wrong side of the garden wall.

Invasive species are bad news for riverbanks. They reproduce and grow with prodigious speed, driving out native plant species. And they're highly resilient. Knotweed can force its way through solid concrete, while giant hogweed contains furocoumarins, sun-activated toxins that can cause skin ulceration. Elimination was a priority – soil was treated throughout the site and the banks stripped of all remaining vegetation.

In addition, Atkins was responsible for ensuring the protection of the existing flora and fauna on the site. Phase one habitat surveys were undertaken as part of the environmental impact assessment in 2006, including bird and fish surveys. A major translocation of species was undertaken to suitable receptor sites including a specially-created 1 hectare site just outside the Park. Atkins translocated 330 common lizards, 100 toads and 4,000 smooth newts. In order to protect the flora on the site, Atkins maintained a 'permit to clear' system for contractors, and specified safeguarded habitat areas that were not to be touched including areas of sycamore trees.

2 Choosing Plants to Plant

Atkins is responsible for the final look of the riverbanks and wetlands-and deciding what to re-plant presented a challenge. With banks now bare, new planting would have to fulfill not

only ecological and aesthetic demands-they'd be expected to be in bloom for the Olympic Games-but engineering imperatives too.

The Atkins design team chose bioengineering techniques, rather than culverting and hard engineering, for the project. That means protecting and consolidating riverbanks by using vegetation and natural products instead of concrete. Choosing the right species with the right root systems would be critical to protect the banks from erosion.

An added challenge was that the river network is semi-tidal. The twice-daily rise and fall of around 400mm had the potential to play havoc with new planting, and the river's high sediment loads threatened to smother anything planted from seed or plugs. "We don't actually have a natural river system," notes Mike. "Plants don't cope well in those conditions."

To find out which plants would fare best-and to establish the most effective planting methods -Atkins conducted a unique riverbank planting trial along a 50-metre stretch of the Lee in the Olympic Park.

"We trialled plants of different elevations and different installation techniques. These were monitored over a year," says Ian Morrissey, senior environmental scientist with Atkins. "That's really helped to inform exactly what species we should plant and where."

The trial revealed that plug plants would be just too vulnerable. But plants pre-grown in coir -coconut fibre matting-resisted being washed away or swamped. Coir has other benefits too-it's easy and quick to install in rolls and pallets two meters long and a meter wide(Fig.03).

"The mat itself acts like a mulch, so you prevent any weeds growing up through it that might already be within the bank material. But more importantly, when the banks become inundated, you get fine sediment trapped within the coir. That helps to bind the roots and feed the plants," says Ian.

3 Banking on Tomorrow's Seedlings

Creating a sustainable riverbank ecosystem means using native species. So before the banks were scraped back, seed was collected from suitable native aquatic species-a process managed by Atkins -and stored in a seed bank. Some of this seed was then used by bioengineering and nursery specialists, Salix, who were appointed by the Olympic Delivery Authority to cultivate plants offsite in what's believed to be one of Britain's biggest-ever nursery contracts.

The offsite growing operation was huge and sowing for the project commenced in June 2009, as plants must be a year old and well established in their coir pallets before encountering the tough riverbank environment.

Plants for the wet woodlands, including sedges, were raised in more than 7,000 pots at Salix's nursery on the Gower peninsula, near Swansea. And in Norfolk, the company created a new 16-acre nursery dedicated to the 2012 project(Fig.04). Here, more than 300,000 plants representing some 28 different species, including sedges, common reed, marsh marigolds and yellow flag irises, were grown on more than a thousand coir pallets, ready to be transported to London in the following months.

During the summer of 2010, the 18,000 square metres of planting were then pieced together like a giant jigsaw. This was a massive logistical challenge. To make it easier, each of the pallets and rolls was tagged. It was vitally important that each one went in exactly the right space so as to avoid cutting and trimming the roots and rhizomes of the plants. The team laid them out in blocks, to a plan, to make sure this didn't happen.

4 Ponds and Wet Woodlands from Scratch

While the riverbanks of the "Old River Lee" occupied much of the attention of the Atkins team, there were also entirely new bodies of water to consider. A fundamental part of the biodiversity of the river edges in the north of the Park lies in three new triangular ponds, off the east bank. Two of these were designed to dry up in the summer, forming moist grassy hollows. The third pond was created to retain water, enabling species such as water lilies and marsh marigold to thrive(Fig.05).

Preventing that third pond from drying out -while also ensuring that it did not flood along with the River Lee-was a conundrum. Atkins responded by designing a connection between the pond and the river to act as both overflow and feed. Flows could be regulated: when the pond level rose too high, water could be drained back into the river; when it started to dry out, a valve could be opened to release river water back into the pond. It sounds simple, but it is believed to be the first of its kind for a habitat feature of this scale.

As well as the improved waterways and riverbanks, new wet woodlands will be a notable feature of the Olympic Park. They're now a rare habitat in the UK, and the ones in the Park are being created from scratch.

"It was quite a novel thing to be asked to do," recalls Atkins' Ian Morrissey. "The challenge was to make sure we had the right water levels within the wet woodland areas. Atkins was responsible for working out the topographies and the channels, and how they would interact with the river."

Wetlands have a tendency to become dry land eventually, a process that can be slowed down through selecting the right vegetation, careful water level management and maintenance.

"The sedge species we selected were chosen because they are quite vigorous so are able to compete well with terrestrial species," says Ian.

Tree species for the wet woodland include willow, alder, birch and the now rare black poplar, points out Atkins' Mike Vaughan: "It's fantastic for wildlife. You get a lot of invertebrates in there, as well as nesting birds."

Birds, though, can present a challenge, particularly on the freshly planted riverbanks.

"There's a risk of wildfowl grazing our plants when they get on site," says Mike. To prevent that happening, hundreds of meters of deterrent fencing were erected around new vegetation. That stayed there until spring 2012(Fig.06).

5 Beyond the Finishing Line

The transformation of the lower Lee Valley and the creation of the new park, now nearing completion, is remarkable by any standards. Visitors to the Olympic Park – up to 250,000 every day at the peak of the Games – will encounter one of the greenest and most environmentally friendly parks ever to be created for the Olympics.

And the benefits will be felt long after 2012. "We're pulling that really difficult trick of putting in infrastructure that's good for the Games, but will work in legacy," said the ODA's John Hopkins. "This will be a great place to live and work, with rivers and parklands at the heart. Socially, economically and environmentally, there will be a terrific legacy-it's a new landscape powering a new piece of city."

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