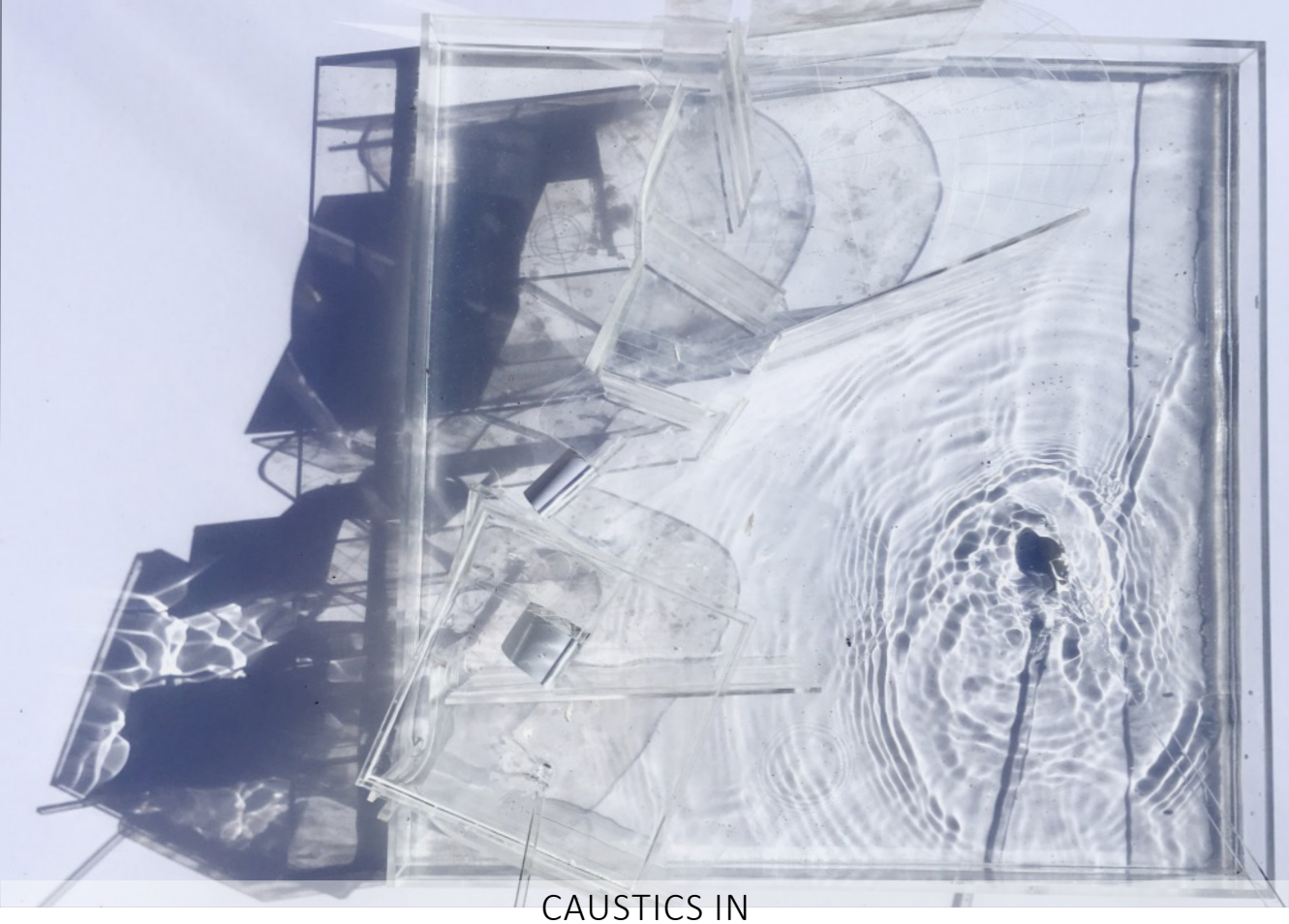

CAUSTICS IN ARCHITECTURE

AN INVESTIGATION INTO THE REFLECTION OF LIGHT: OFF WATER, CREATING CAUSTIC PATTERNS

Sally Dawn Taylor

MArch Architecture Thesis
April 2017

Fig. 1. Cover: Author's own: Testing caustic reflection and projection

CAUSTICS IN ARCHITECTURE

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BENV GA05 YEAR 5 THESIS
MArch, BARTLETT SCHOOL OF ARCHITECTURE, UCL

April 2017

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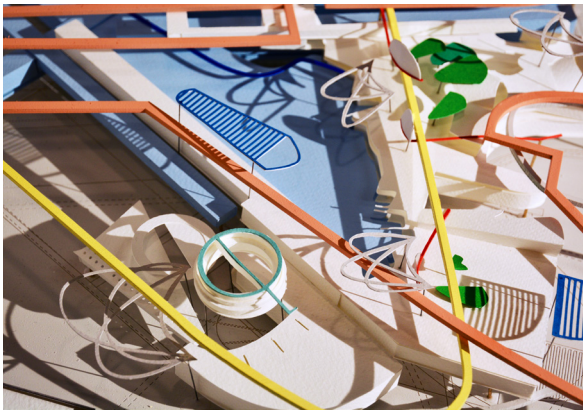


Fig. 2. SAD Landscape model photograph

WORD COUNT: 7,930

Fig. 3. SAD Landscape detail

The term ‘light’ covers a vast array of different conditions within nature, as well as architectural contexts. In Scandinavia, light is an extremely variable, yet important aspect of Nordic life. There are many different lighting condition examples which all provide a very different feeling within a space. Some of these include diffused light, cinematic light, softened and reflected light.

Within this study, I will be concentrating on one particular type of lighting; reflections, specifically off the water, which will allow me to investigate, test and generate ideas, resulting in an architecture which works around the unique reflecting light qualities in Sweden. I will be using physical modelling as a primary working method; The thesis research will be in the context of Stockholm, creating a relaxing space for visitors, some of whom suffer from Seasonal Affective Disorder during the dark months of winter. Due to the significant seasonal variations of the North, which is characterised by days of very little or too much sun, and year-round low angle sunlight, both natural and artificial lighting will be explored.

Fig. 4. Scandinavian Seasonality - Spring, summer, autumn and winter

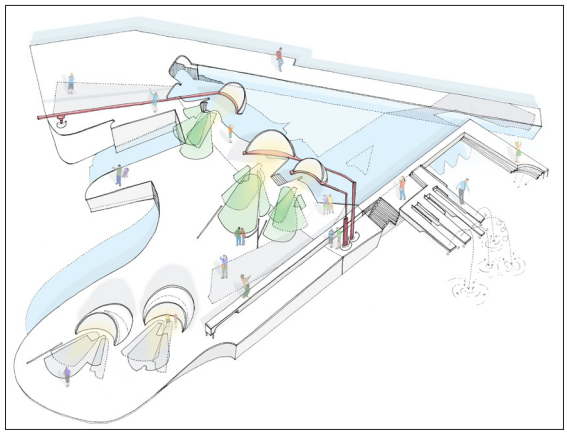


Fig. 5. SAD Landscape detail

CONTENTS

Fig. 6. Scandinavian summer

SCANDINAVIAN LIGHT AND SEASONALITY

"But you still need the two: the dark and the light. You can't see one without the other."

Julia Green, Drawing with Light

The length of a day varies more dramatically in the Nordic region than most other places in the world. The low slant of the sun in winter and high latitudes result in long shadows and strikingly refracted colours, due to the light passing through more atmosphere, it is usually warmer in tone; for this reason, both dusk and dawn also last longer in this region. With a sun angle of only eight degrees, the winter in Sweden is almost horizontal and certain moments come from below the horizon line. (Plummer, H: 6) These factors mean that Nordic light is particularly unique, with only a few percent of the world's population living in these types of light conditions. From 60 degrees' latitude northwards, roughly on a level with the capitals of Oslo, Stockholm and Helsinki, the difference between day and night during the summer and winter are so great that it really is relevant to talk about light and the impact that this has on everyday life. (Nordiska Museet)

SUMMER

Stockholm Sunrise/ Sunset

JULY

Sunrise: 3:40AM
Sunset: 10:02 PM

Total hours of daylight = 19 hours
Sun angle = 45 degrees

Fig. 7. Foynland in Norway, June 2014

Fig. 8. Foynland in Norway, June 2014

WINTER

Stockholm Sunrise/ Sunset

JANUARY

Sunrise: 8:47AM
Sunset: 2:55 PM

Total hours of daylight = 6 hours
Sun angle = 8 degrees

Fig. 9. Hamar, Norway, October 2016

Fig. 10. Stockholm, Sweden, October 2016

KEY

1 De Besches Vag to Djurgardesvagen
2 Djurgardsbrunnsviken
3 Rosendalsvagen to Prins Eugens Waldermarsudde
4 Nordiska Museet
5 Entrance to Maritime Museum
6 Skansen
7 Lidovagen

Fig. 11.

Map showing mix of seasons on Green Lung taken from Bing Maps. Data glitches have caused clear borders between summer and autumn to be created. This provides a direct contrast where colours of each season can also be seen clearly.

During winter the Nordic region has limited daylight, while in summer, with a maximum sun angle of fifty degrees, the sun is up for almost twenty-four hours. These aspects have helped to provide the context for a unique way of developing architecture. Despite advancements in artificial lighting over recent centuries, daylight is still our primary source of light. Daylight hours affect day to day activities, our temperament and synchronisation of body clocks; an example of this is sleeping patterns, the average Swede sleeps ten hours in winter, compared to only five or six hours during the lighter, summer months. Light is known to have many health benefits and has a profound effect on both our immune systems and emotional stability.

Having experienced Scandinavia first hand in both summer and winter, I began my academic year looking at the main contrasts between the two seasons. This resulted in designing in response to the environment and seasonal routines, working alongside natural light at all times of the year. Shadow studies and sun path diagrams for my site in Stockholm have enabled me to analyse patterns, leading me to further develop my architectural knowledge within this unique quality of light. Physical and digital modelling have allowed for a three-dimensional aspect of Nordic light to be studied, where light intensity and movement of the sun can be investigated and mapped accurately. This results in a distinctive way of developing architecture, which is incredibly unique to Stockholm, with the possibility of it being transferred to other parts of Sweden and Scandinavia.

Stockholm is known as the 'City of Water' and spreads over 14 islands, with 57 bridges connecting the city. (Nelson, 2017) There are strict planning regulations in place to ensure humans are close to nature and that natural areas maintain their ecological functions. Because of these regulations, the cities' land area is nearly one third urban, one third water, and one third green space. The city comprises of a 'Green Lung', it is known as the recreational island and is surrounded by water. The contrast between winter and summer here is extremely noticable due to the amount of greenery, which turns into red and brown hues during autumn. As well as affecting the natural surroundings in Stockholm, the seasons, notably levels of sunlight, have a huge impact on the people of Scandinavia.

Fig. 12. Scandinavian winter

METHODOLOGY

The investigation is divided into two parts; the first part will look at the light in the context of Scandinavia, and the effect this unique lighting condition has on its surroundings. This includes the advantages and behavioural effects of light on the Scandinavian population. I will look at methods used to incorporate daylight into art and architecture, specifically focusing on reflections. My design, based in Stockholm in Sweden, will tie these two aspects together.

The second part will investigate a series of physical studies, focusing on the reflection off the water, creating caustic patterns. I will look at examples and precedence that use reflections; this will include artwork, installations, nature and architecture. The outcomes will provide a clear understanding of ideas that can be looked at and tested, primarily through physical modelling, which will further inform my design. Working with the specific lighting conditions of Stockholm, in both summer and winter, I will explore the conditions that allow for optimum caustic reflection within a unique setting. Due to the seasonal contrasts in sunlight, the physical tests will include the use of both natural and artificial lighting conditions.

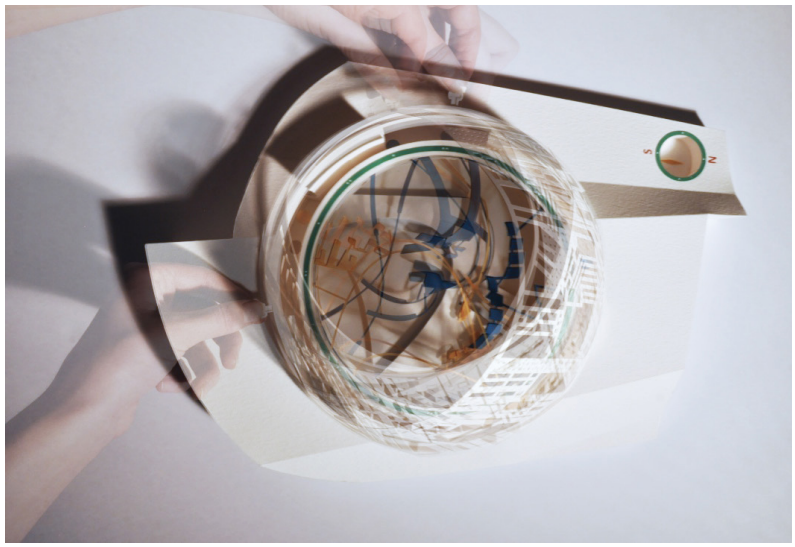
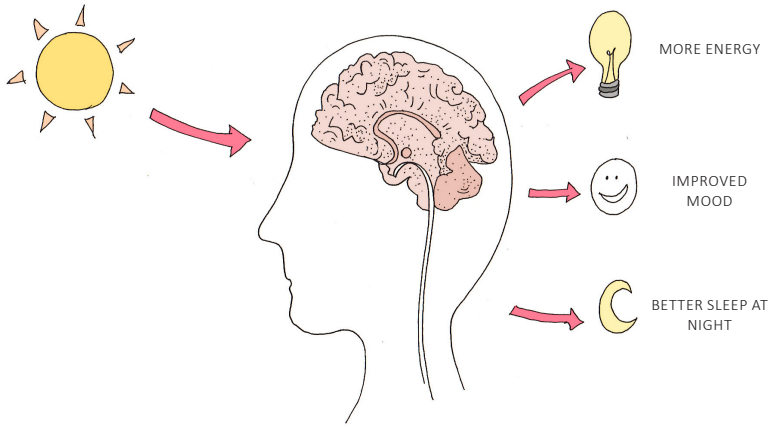


Fig. 13. 'Stuga' model showing relationship between Stockholm light and shadow location

Fig. 14. THE EFFECT OF SUNLIGHT ON THE BODY:



1 Sunlight enters through your eyes

2 Acting through the hypothalamus, sunlight regulates our circadian rhythm through complex pathways that include melatonin, serotonin and body temperature.

3 Improving your circadian rhythm has dramatically positive effects on your body and mood.

THE EFFECT OF LIGHT ON THE SCANDINAVIAN POPULATION

Historically in Rome, where the sun does not go, the doctor does; gloom and darkness were associated with an emotion which physicians named 'melancholia', revealing the link between low levels of light, and sadness and despair, to be an ancient one. Lack of sunlight meant weak bones, muscles and ill health. Not only the Romans, but throughout the ancient world. Greeks and Egyptians also worshipped the sun's healing powers. (Hobday, R: 10)

Although much remains to be discovered about the mechanisms through which bright light exerts its beneficial effects, light has been used to treat conditions such as Seasonal Affective Disorder (SAD) and seasonal depression for some time. In 2002 scientists made a discovery that the rate of production of serotonin by the brain was directly related to the duration of sunlight which in turn can determine how cheerful or depressed we are. (Hobday, R: 11)

During autumn and winter months in Scandinavia, the ultraviolet radiation in the sunlight starts to fall below the threshold level at which we can synthesise Vitamin D in our skin. Between the autumn and spring equinoxes, we cannot rely on the sun for our supplies of Vitamin D. Unless supplements are taken in our diets, we purely depend on the stores we have built up during the summer months. By the middle of winter, most of our reserves are gone. (Hobday, R: 24)

In Scandinavia, with long dark winters, low levels of sunlight and Vitamin D can cause many health problems. Eleven percent of Swedes have some form of winter depression, and eight percent have Seasonal Affective Disorder. (Reuters, UK) The symptoms of Seasonal Affective Disorder (SAD) are similar to those of normal depression, but they occur repetitively at a particular time of year.

They usually start in the autumn or winter and improve in the spring. Symptoms for SAD listed on the NHS website include:

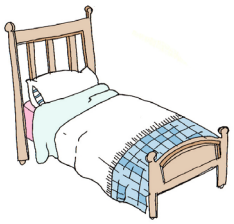
- A persistent low mood
- A loss of pleasure or interest in normal everyday activities
- Feeling irritable
- Feelings of despair, guilt and worthlessness
- Low self-esteem
- Tearfulness
- Feeling stressed or anxious
- Becoming less sociable
- Being less active than normal
- Find it difficult to concentrate

(Nhs.uk, 2017)

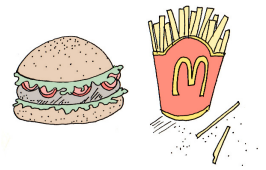
Some people with SAD find that light therapy can help improve their mood considerably. This involves sitting by a special lamp called a light box, usually for around thirty minutes to an hour each morning. The light boxes used provide the viewer with a diffuse source at eye level, rather than a direct beam to simulate skylight rather than sunlight. (Hobday, R: 37) When regular exercise and bright light are combined, the psychological benefits increase significantly. (Hobday, R: 45)

With almost a million sufferers of Seasonal Affective Disorder in Sweden, Light cafes are a new trend which is starting to become more and more popular. During winter months, when Stockholm only receives around five hours of daylight, commuters can stop off in cafes and sit bathing in UV-free lighting with a strength of 3,000 lux (pictured opposite). This intense light, which is much greater than the 200-500 lux emitted by household or office lighting, along with the white washed wall for further diffusion of light, helps to simulate natural daylight and is, therefore, able to correct the hormone imbalance that results in SAD. (Carlowe, 2017)

Fig. 15. Illustrated SAD Symptoms



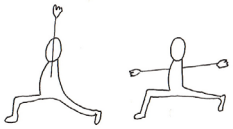
Feel lethargic (lacking in energy) and sleepy during the day sleep for longer than normal and find it hard to get up in the morning



Have an increased appetite – some people have a particular craving for foods containing lots of carbohydrates and end up gaining weight as a result

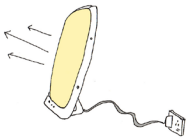
Fig. 16. TREATING SEASONAL AFFECTIVE DISORDER

Sit near windows when you're indoors



Take regular exercise and try relaxation techniques such as meditation and yoga

Eat a healthy, balanced diet



Light therapy - the recommended light boxes have filters that remove harmful UV rays,

Fig.17. A Light Therapy Café in Stockholm called 'Igloo', brightens dark winter months

Fig.18. Light Therapy Café, Stockholm

Fig.19. 10 Foods to Help Ease the Winter Blues:

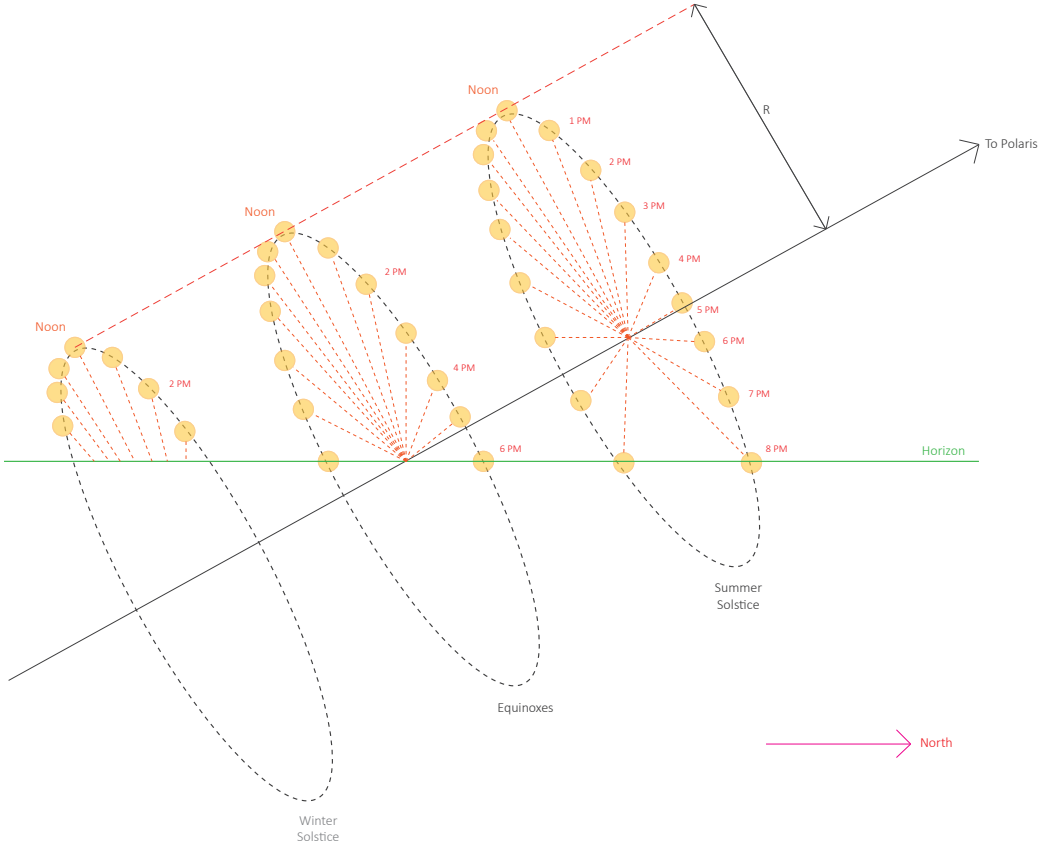
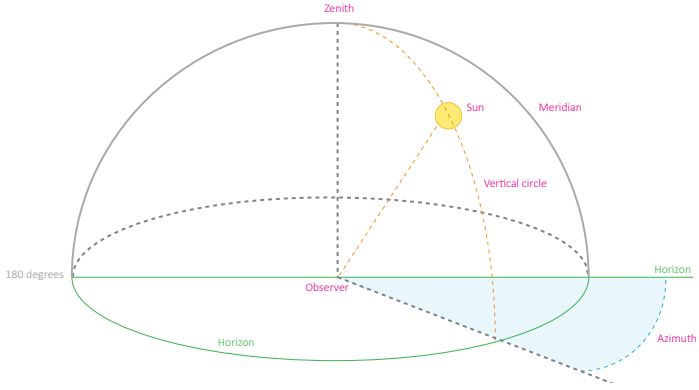


Fig.20. Diagram illustrating the variation in the sun's movement in relation to latitude.



Sunrise and Sunset: Stockholm, Sweden

Period	Sunrise	Sunset
January	8:47am	2:55pm
February	8:01am	4:01pm
March	6:48am	5:12pm
April	6:17am	7:26pm
May	4:52am	8:37pm
June	3:47am	9:44pm
July	3:40am	10:02pm
August	4:35am	9:13pm
September	5:46am	7:50pm
October	5:54am	5:21pm
November	7:08am	3:54pm
December	8:19am	2:54pm

Fig.21. Diagram illustrating the variation in the sun's movement in relation to latitude.

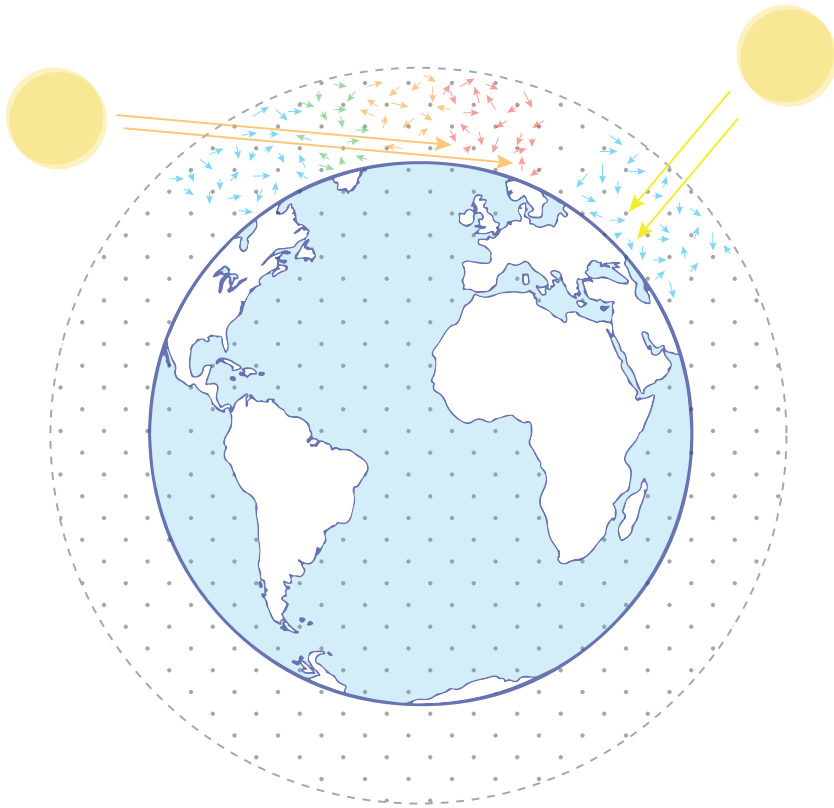
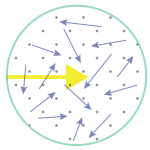


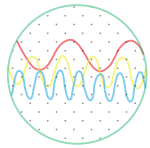
Fig.22. Diagram illustrating why the sky is blue and how colours change when the sun is lower in the sky

When the sun is lower in the sky, sunlight travels a longer distance through the atmosphere to reach an observer.

This means it encounters more particles that scatter out most of the blue light, as well as some green and yellow light. This leaves mostly RED light when the sunlight reaches the observer.



Small particles which make up the earths atmosphere scatter the sunlight as it passes through it



Each wavelength of light is scattered to a different degree,the graph on the right shows the amount each colour is scattered when the sun is directly overhead

More BLUE light than other colours is scattered out of the sunlight travelling through the atmosphere.

This creates a diffuse blue glow, and makes the sun appear yellow in colour.

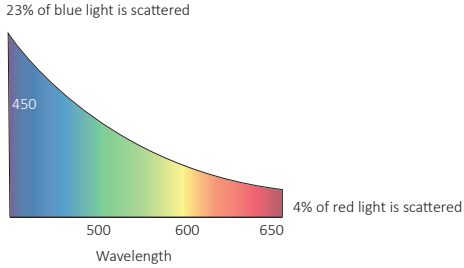


Fig.23 PHOTO CATALOGUE OF WINDOW SHUTTERS IN STOCKHOLM:

During summer, the long hours of daylight result in the opposite problem to what faces Swedes during winter: too much light. As the sun does not set until late in the evening during long summer months, shutters are required on windows to allow for shading and darkness at bed time. Here is a photo catalogue showing traditional, vernacular designs, as well as more modern shutters and shading on windows and facades in Stockholm, Sweden. This includes wooden shutters and fabric shutters that can be adjusted depending on the time of day and year.

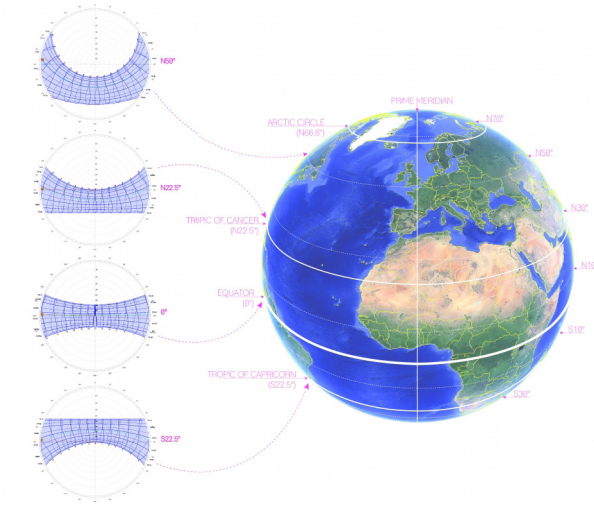


Fig.24. Stereographic sun path diagrams are used to read the solar azimuth and altitude throughout the day and year for a given position on the earth. They can be likened to a photograph of the sky, taken looking straight up towards the zenith, with a 180° fish-eye lens. The paths of the sun at different times of the year can then be projected onto this flattened hemisphere for any location on Earth.

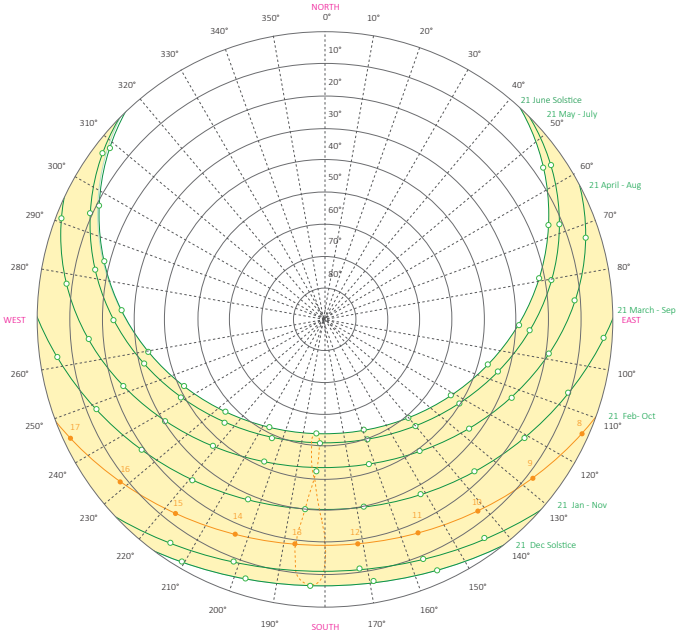


Fig.25. Stereographic sun path diagram for Stockholm, Sweden

SITE LOCATION: Stockholm, Sweden

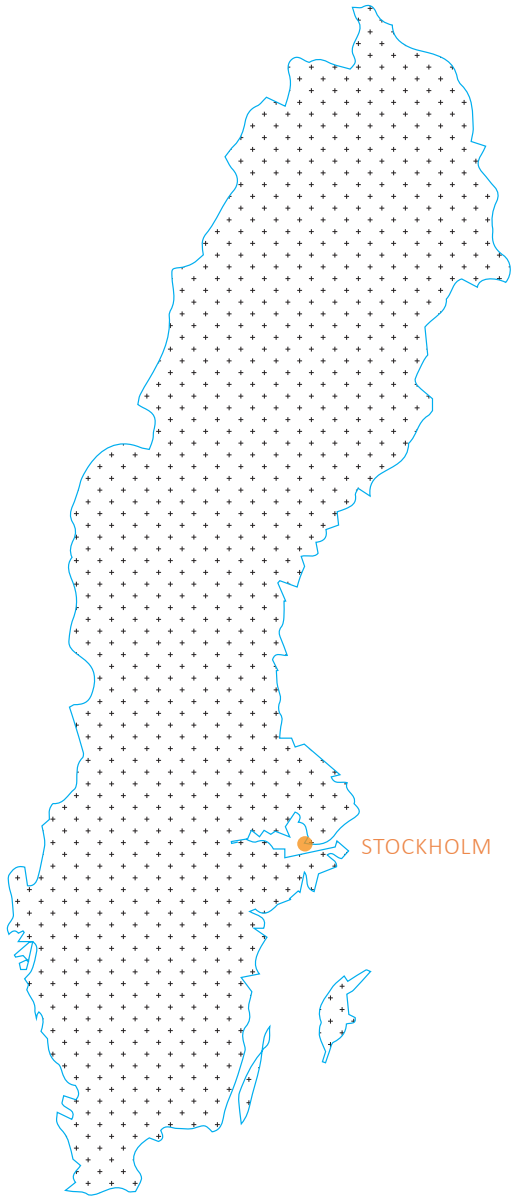


Fig.26. Map of Sweden, with Stockholm marked out on the East coast.

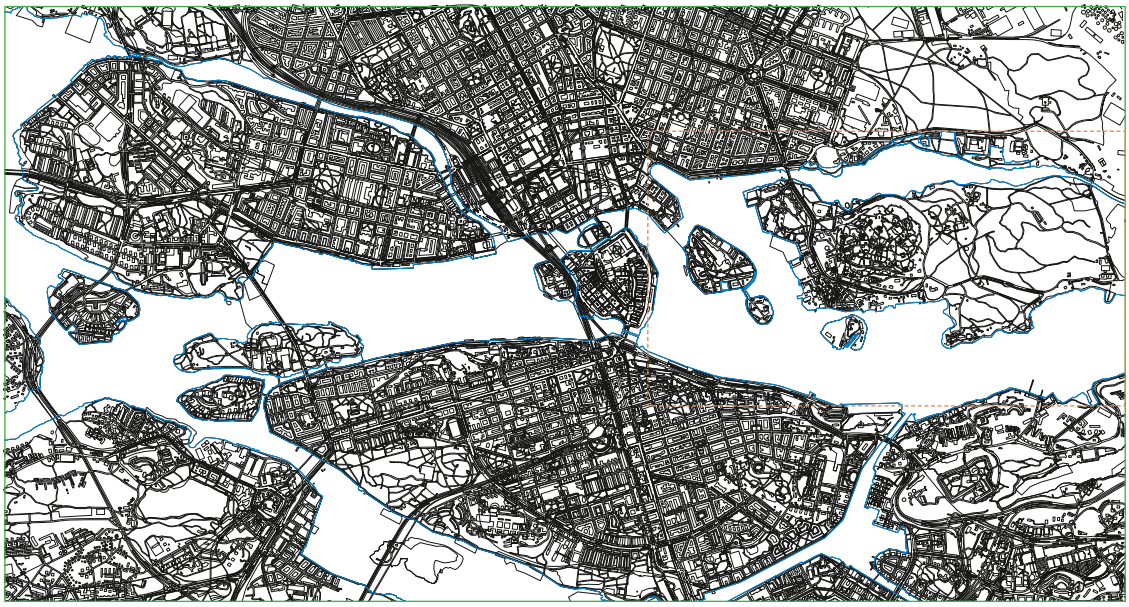


Fig.27. Map of Stockholm, Not to Scale

Fig.28. Map of Stockholm's Djurgarden: A green lung for the city, Not to Scale

DESIGN PROPOSAL - THE SITE

Stockholm consists of a recreational island called Djurgården; also known as the city's 'Green Lung'. This is where people who live in the city go in order to escape the confines of their homes and offices, which mostly consist of artificial light. Located here are twenty of Stockholm's museums and attractions, situated in the Royal National City Park. Stockholmers take pride in their enjoyment of outdoor life, which is evident in the fact that ten percent of the Swedish population own a summer house and ten percent own a leisure boat, most of them living in big city areas. (Sustainable Swedishness, 2017)

Stockholm's water is so clean that you can fish for salmon, swim in it or even drink it and during summer months this bay, Djurgardsbrunnsviken, is relatively calm and clear. During autumn and winter the water's surface is slightly more disturbed; but this, along with the low angle of the sun, results in a glistening effect across the waters surface. It is clear to see the change in cloud cover above within the water reflections, which changes the colour and tone of the bay.

Due to the high percentage of Swedes who suffer from Seasonal Affective Disorder, this year my design has looked at creating a retreat from the winter blues within this recreational setting. The location of this new landscape is along the water's edge, within the 'Green Lung'. Reflection will therefore play tremendous importance in allowing light, and the patterns this creates, into the spaces I construct. The SAD landscape design has been formed using shadow studies of Stockholm; these studies were carried out for the longest and shortest day of the year in order to show the vast variation. The lightest areas, which are not in shadow, will be the zones in which the new masterplan will be constructed. The studies, as well as a Masterplan drawing showing how the shadows have helped form the landscape scheme, are shown on the next few pages.

Fig.29. PANORAMA TAKEN ACROSS WATER ON NORTH SIDE OF GREEN LUNG

Sun illuminates trees and shrubbery

Colours are dull in clouded over area

Choppy water in wind

GREEN LUNG AERIAL VIEWS

Fig.30.
Aerial view showing Nordiska Museet and Vasamuseet and park areas with pathways along waters edge. The Green Lung is connected by trams.

Fig.31.
The Maritime Museum in Stockholm, Sweden is a museum for naval history, merchant shipping and shipbuilding. and many maps are on display.

Reeds growing in shallow water areas

Lights along pathway for dark mornings/ evenings

Refelective water

Calm and rough water reflect different amounts of light

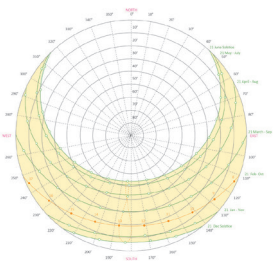
Dappled shaded areas created by trees

Leaves fall to ground

Fig.32. STOCKHOLM SHADOW STUDY: WINTER/ SUMMER

SUMMER AND WINTER SHADOW STUDY
DRAWING KEY

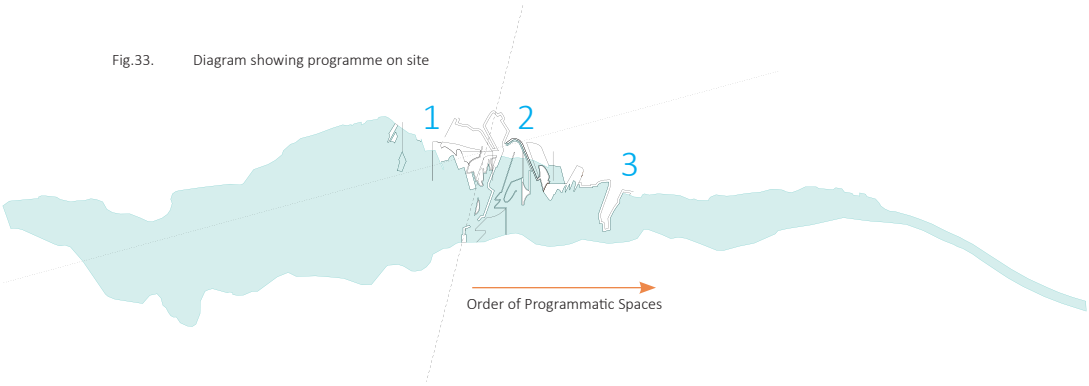
- Winter Shadow cast
- Summer Shadow cast
- Summer Shadow pattern
- Winter Shadow pattern
- Summer Seasons
- Winter Seasons
- Baltic Sea
- Stockholm city outline



PROGRAMMATIC SPACES

A continuation of the path along Djurgardsbrunnsviken

Fig.33. Diagram showing programme on site



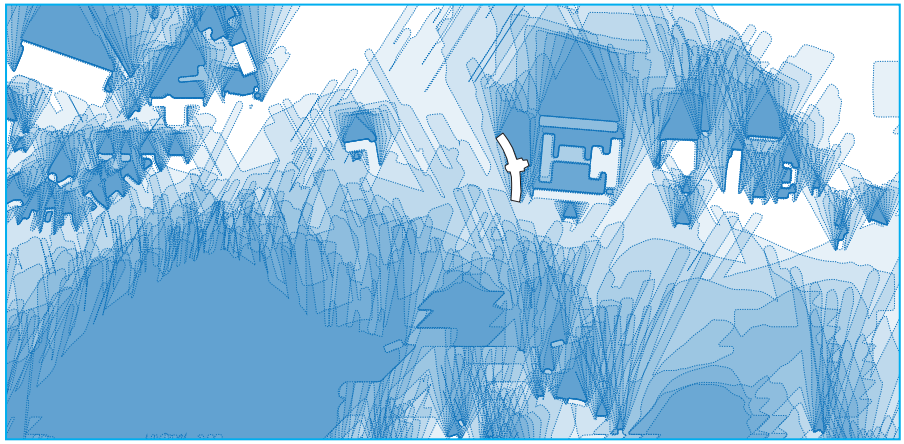
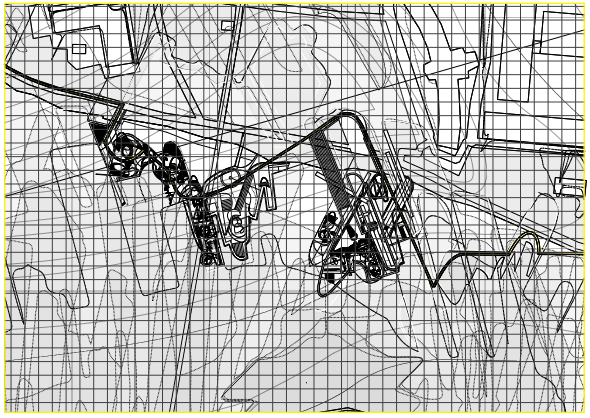


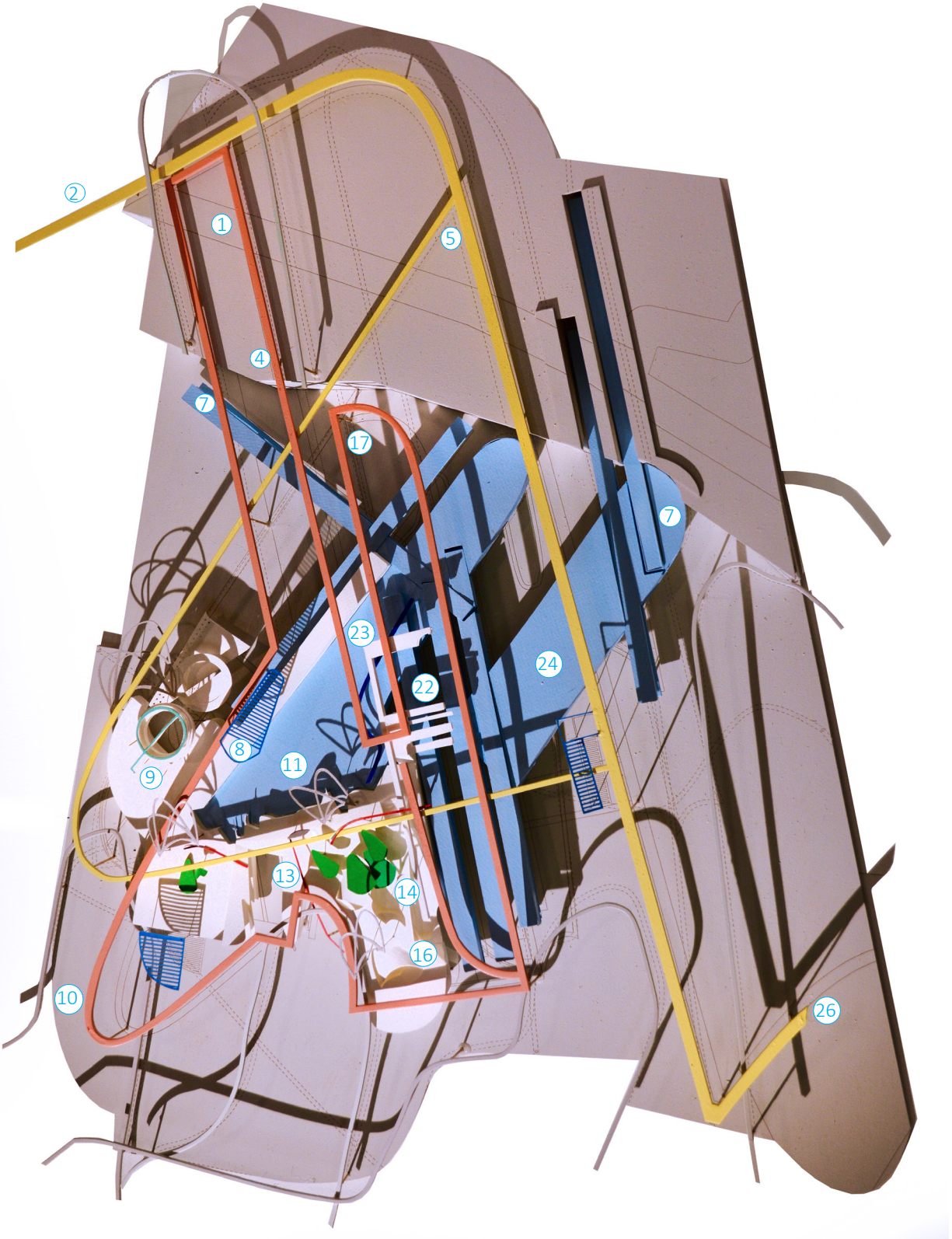
Fig.34. Site shadow study: Winter/ Summer

Fig.35. MASTERPLAN OF SAD LANDSCAPE SCHEME (NOT TO SCALE - 1:500 AT A1)



[Fold out for larger image]

Fig.36. EXERCISE LANDSCAPE MODEL, Plan View (1:200 at A1)



DESIGN PROPOSAL - SAD LANDSCAPE

In Northern Europe, there is an ice swimming tradition which has been connected with the sauna tradition. It is a way to cool off rapidly after staying in a sauna and also acts as a stress relief. Winter swimming contributes to better general well-being. When compared to a control group on the profile of mood states rating scale, winter swimmers experience less stress and fatigue and more vigour. They report to have a better memory function, better mood and feel more energetic, active and brisk. (Huttunen, P: 140)

Using shadow studies to develop the form, within part of the SAD Landscape Masterplan proposal there will be an area dedicated to exercise in order to help people suffering from the winter disorder. This will help to alleviate some of the symptoms discussed earlier. Although this is an area that can be enjoyed by visitors during winter months, it can also be experienced through all seasons and weather conditions, therefore all lighting conditions will need to be considered.

The exercise landscape includes pathways, running tracks, cold water swimming pools and a relaxation area; which is adjacent to the water's edge. There will be spas, steam rooms, yoga lessons and changing facilities situated within this zone (number 14 in the diagram opposite). Taking advantage of the water front position of the scheme, I will be looking at ways to incorporate light and nature from the surrounds into the SAD Landscape proposal, predominately through reflection.

KEY

SEASONAL DISORDER LANDSCAPE
Djurgarden: Stockholm, Sweden
Scale 1:200 at A2

N

1. Existing pathway along bay
2. New proposed pathway route
3. Enter new landscape structure
4. Running Tracks
5. Secondary pathway
6. Bridge stretching over bay
7. Swimming training lanes
8. Shading canopy
9. Rotating accommodation
10. Route around pool landscape
11. Shallow cold swimming area
12. Summer shading canopy
13. Large rotating reflector
14. Focused sunlight drying area
15. Light slits for caustic projection
16. Summer reflector
17. Running track
18. Large rotating reflector
19. Focused sunlight drying area
20. Focused light capture space
21. Focused light capture spaces 1,2&3
22. Diving area
23. Viewing platform
24. Large swimming pool
26. Path continues to next landscape piece

THE LIGHT OF THE NORTH

"*Architecture is a preparation for the experience of light*"
Juhani Pallasmaa (Plummer, H: 13)

After Christmas in Sweden, everyone's mood improves. Snowfall is heavier and more frequent, so although the days are still short, the little light they receive is reflected off the snow, giving the impression of a much lighter environment. It's at this time of the year that Swedes take to the great outdoors, cross-country skiing, ice skating or even a brave cold water swim.

Dark Scandinavian winters are composed of many natural marvels; soft blurs of fog and mist, glistening ice, starry nights, violets of dusk, aurora and blankets of white snow. Against the backdrop of darkness, these elements create a unique mixture of realism and magic. Architects of the 1930's tried to tie in aspects of these elements that Plein air artists had successfully done. Such work was produced by the artist Akseli Gallen-Kallela, a Swedish speaking Finnish painter. During the early twentieth century he completed a series of Scandinavian winter paintings with particular attention to light and shadows; here there is a pristine beauty in these snow covered landscapes. Around a similar time, Scandinavian architects loosened their buildings from the formal and mechanical stress of modernism, and sought instead to naturalise simple volumes by 'suffusing them with light distinct to the north'. (Plummer, H: 7)

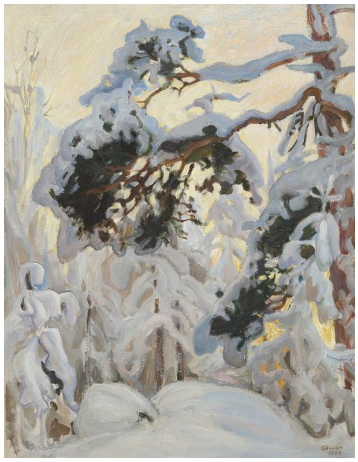


Fig.37. Akseli Gallen-Kallela, Winter forest, 1900

Fig.38. Akseli Gallen-Kallela, Sunshine on Snow, 1906

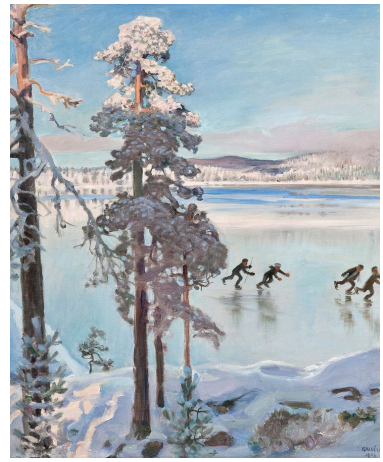


Fig.39. Akseli Gallen-Kallela, 1896

Fig.40. Viipuri Library exterior on a winter's night

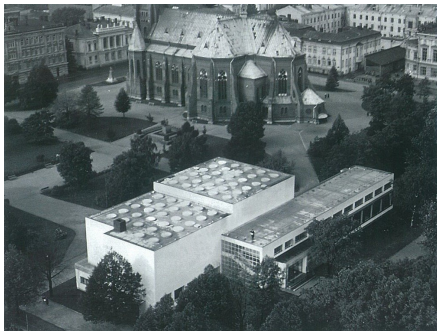


Fig.41. Pre-1940 photo of the library adjacent to the Cathedral

Fig.42. Viipuri Library exterior on a summer's day

A notable example of this was portrayed in Alvar Aalto's Viipuri Library in Russia. Built in 1935, it comprises of plateaus illuminated by conical skylight's giving the effect of sun movement during the day. For buildings such as this, a softer light was required, resulting in sunlight being tempered by multiple reflections in order to achieve such an effect. (ArchDaily)

From exploring lighting conditions in Scandinavian architecture, it is clear to see that light plays an exceedingly dominant feature within design. In more recent decades, Nordic architecture expands the creative scope of the eye as well as mind, requiring people to sense rather than just see. (Plummer, H: 10)

Lighting can be used in many different ways and architecture can be used as an optical instrument for this, with light being collected from certain points on the horizon. An example of this is Männistö Church, Finland, built in 1992, by Juha Leiviskä and Pekka Kivisalo. Hidden patches of paint on the rear walls reflect coloured light. The faint colours are magnified by a white back drop and colours are replaced by sharp sun rays entering the church. Reflective finishes prevent light from being absorbed, therefore helping to illuminate the space further. Pale surfaces act as a 'projection screen upon which subtle daylight can be exhibited and intensified'. (Plummer, H: 8) White rooms offer a means of staying near the most elusive aspects of nature: delicate skylight and mercurial weather, and the shifting moods of the hours and seasons. (Plummer, H: 16)

Scandinavians seem to have an inclination to live closely to the environment around them. For them, sunlight is a precious source of heat, illumination and well-being in a world that is often frozen and dark. "The allure to light increases dramatically against a dark backdrop." (Plummer, H: 74) Nature in this sense is more about the interpretation rather than exact resemblance. For example, through the use of curved tiles, Alvar Aalto translates and recalls the play of light across a lakes surface. (Plummer, H: 9)

Many artists use light in order to create an experience and interpretation rather than for purely the illumination of objects. Olafur Eliasson uses light to arouse a particularly creative human response, particularly in 'The Weather Project' located within the Tate Turbine Hall in 2003. He states that different weather and lighting effects combines the singularity with the collective. These elements change the way a person views the space and "challenges the way you create maps" (May, S: 110)

Fig.43. The Weather Project, Tate Modern, 2003

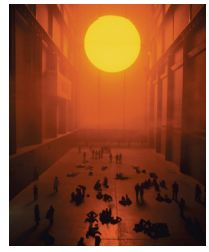


Fig.44. The Weather Project

Olafur Eliasson
The Weather Project, 2003
Monofrequency lights, projection foil, haze machines, mirror foil, aluminium, and scaffolding

Fig.45. Männistö Church by Juha Leiviskä in Kupio. Finland

Fig.46. Photo of the interior of the Männistö Church designed by Juha Leiviskä.

REFLECTIONS; BRINGING THE OUTSIDE IN

"Architecture is the writing in the landscape"
(Sverre Fehn in Dag og Tid 1996)

Having looked at the interpretation of nature within architecture, one way to feel the presence of the outside within a space is through reflection. Reflection of light allows for the most elusive and delicate aspects of nature to enter a space, as well as the shifting of hours and seasons. During the summer months, many Swedes spend a lot of time in lakeside cabins and huts, known as a Stuga, which are commonly located near lakes.

Since ancient times, humans have assigned healing and transformational properties to water. In early Rome, baths were an important part of cultural life, a place where citizens went to find relaxation and to connect with others in a calming setting. Rivers have long been seen as sacred places, and in a number of different spiritual contexts, water has symbolised rebirth, spiritual cleansing and salvation. (The Huffington Post) The calming effect of being by the water allows for relaxation and an escape from the hustle and bustle of everyday life, which may in turn alleviate some of the earlier discussed symptoms of Seasonal Affective Disorder. With a site that is protruding out onto the water, it makes sense that reflections from the water surrounding the landscape can be reflected into the proposed scheme. Due to the almost horizontal light during winter months in Sweden, creating architecture that allows reflected light in is a very unique design method. With the large amount of snow fall in winter, a lot of light is reflected from the ground as the whiteness scatters light very efficiently.

The Ivar Aasen Centre by Sverre Fehn is a built example of where reflected architecture has informed the design of a building. Due to the weather and large amount of snow fall, during winter months a lot of light is reflected by snow fall on the ground and the architect is conscious of light coming from below, up into the building, and uses this to his advantage; angled windows directs our attention towards the landscape and captures light being reflected from the ground below. (The Architecture of the Ivar Aasen Centre)

Fig.47. Ivar Aasen Centre, Ørsta, 2000

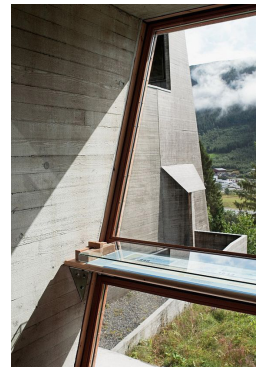


Fig.48. Ivar Aasen Centre, concrete/ glazing junction detail

THE EFFECT OF WATER ON LIGHT

Water has numerous effects on light. When entering water, light is either reflected from its surface, scattered from within the volume of water or it is reflected from the bottom of the container.

The light rays, which are reflected or refracted by water, create some areas of focused and defocused light. Concentration of light, especially sunlight, can burn. Latin for burning is causticus and as a result the term 'caustic' is used for describing the effect produced by this focusing and defocusing.

Caustic definition: ***"envelope of light ray reflected or refracted by a curved surface or object, or the projection of that envelope of rays on another surface"*** (Weinstein, L.)

A familiar example of optical caustics is the bright line seen next to a glass cup on a bright sunny day. The glass casts a shadow, but also produces a curved region of bright light: here the caustic is formed by the envelope of light rays reflected by the curved surface of the cup. Rippling caustics are commonly formed when light shines through waves on a body of water. The undulating water surface projects patterns of sunlight called caustic networks onto nearby surfaces, these are best seen when the waters depth is about five times the waves crest to crest distance.

The water's surface can be seen as a series of positive and negative lenses which focus and defocus light onto the bottom of the pool. The upper surface acts as an array of curved mirrors which focus and defocus sunlight.

Fig.49. Caustics created by cup of water

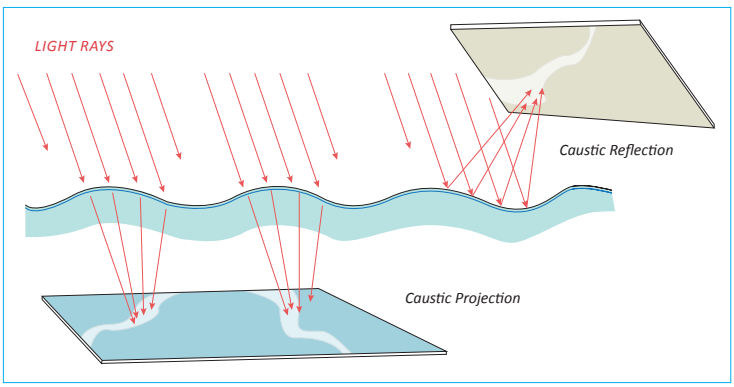


Fig.50. Diagram showing how the caustic network is created

Caustic Reflection
In reflection, the upper surfaces also act like an array of curved mirrors which focus or defocus sunlight.

Caustic Projection
The water's surface behaves like an array of alternately positive and negative lenses which focus and defocus light onto the bottom.

CAUSTIC PROJECTION

The combination of focusing and defocusing of the light rays creates regions that are in crude focus and therefore bright. Those out of focus are dark. These patterns are beautifully illustrated in David Hockney's paintings.

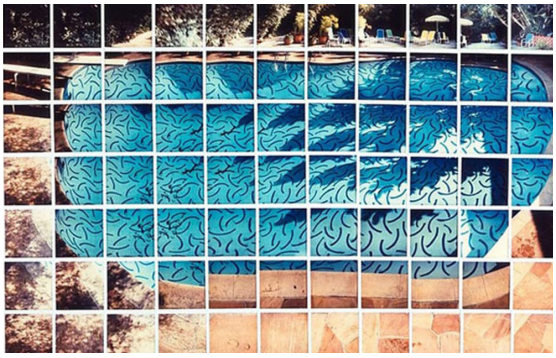


Fig.51. "Sun on the Pool" 1982

Fig.52. "Portrait of an Artist (Pool with Two Figures)" 1972

Fig.53. Picture of a Hollywood Swimming Pool, 1964

CAUSTIC REFLECTION

When light reflects off the water's surface, these caustic patterns are visible within the reflection; with focused and defocused sunlight creating a similar effect above the water's surface as below it.

The caustic lines and patterns reflected depend on the pattern of waves which the light is bouncing off. The caustic reflections visible on Venetian bridges are fairly parallel to each other, because the calm waters are too.

In order for caustic patterns to be visible, the light needs to be hitting the water at a low angle, which in turn allows for a greater amount of light to be reflected upwards. These reflections spread out, and in this example, go a little out of focus on the near side of the bridge.

With a site protruding out onto the large open bay of Djurgardsbrunnsviken and with the low Scandinavian sun, as low as eight degrees during winter, I have decided to focus my testing and analysis around caustic projections and reflections. My aim is to further enhance such effects as seen in Venice, in order to create a relaxing, calming space for sufferers of Seasonal Affective Disorder to appreciate in winter, as well as other times of the year.

CAUSTIC REFLECTION EXAMPLES:

Fig.54. Caustic patterns on a fishing boat hull, generated by sunlight reflected from the undulating sea surface.

Fig.55. Caustic reflection on cave entrance wall

Fig.56. Caustic reflection on Venitian bridge

Fig.57. Caustic reflection on Venitian bridge

Fig.58. Photograph showing later testing of: ceating caustic reflections in natural daylight

The following pages document the physical testing of both caustic projection and caustic reflection. These have been carried out using both artificial and natural daylighting in order to cover all seasons and sunlight conditions. Precedence has been studied alongside these tests in order to gain further understanding.

These tests have been listed below:

Test One	Caustic Projections
Test Two	Water diffraction
Test Three	Creating caustic projection effect
Test Four	Creating caustic reflection effect
Test Five	Caustic Reflection
Test Six	Multiple Caustic Reflections
Test Seven	LED Lighting/ Materiality
Test Eight	Sunlight/ Materiality
Test Nine	Component Materiality

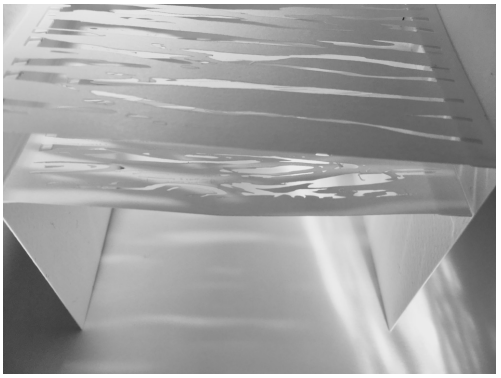
These tests are followed by a series of images of a final model, which has been deveoped using the findings from each test that was carried out.

[NOTE: All testing and analysis images and diagrams are author's own unless otherwise specified]

CAUSTIC PROJECTION: TEST ONE

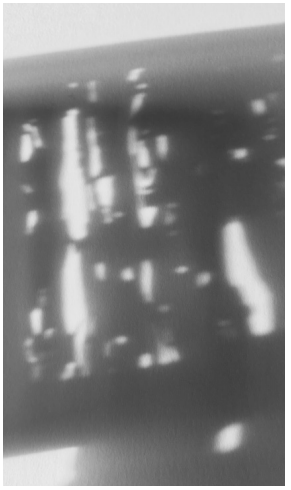
For the first test I have tried to create the caustic projection effect of light through water. This was done by cutting out ripple effects onto multiple 'screens' and layering these underneath a single light source.

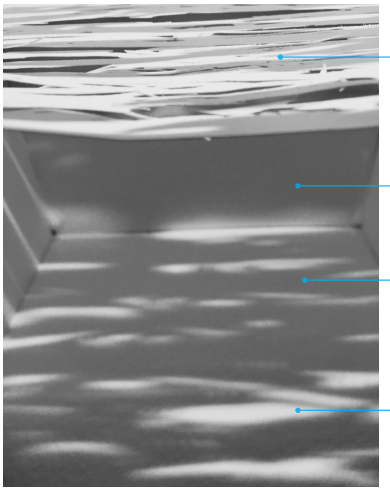
Test Setup:



Caustic projection: sketch model view from above

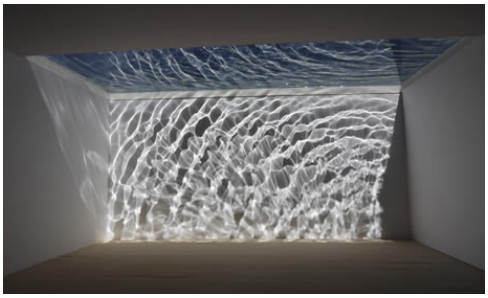
Caustic projection effect patterns





The resultant shadow effects are fairly successful and gives the impression of water, although this does not convey any movement of the water's surface and volume.

CAUSTIC PROJECTION IN ARCHITECTURE
Precedence Research:



LIGHTWAVE / PHILIPPE BOMPAS

The transparent ceiling in this pavilion is covered by a layer of water. The surface of the water is moving due to a light breeze. Sunlight is projected into the room, creating a flow of caustics, “morphing according to the perturbation of the water surface”. (Lightwave, BOMPAS)

Fig.59. Caustic projection: Philippe Bompas

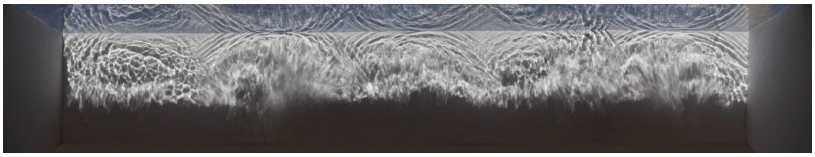


Fig.60. Caustic projection: Philippe Bompas

Fig.61. Caustic projection in Shaw House by Patkau Architects

SHAW HOUSE / PATKAU ARCHITECTS

The Shaw house is located on a narrow waterfront property on the south shore of English Bay. The pool, with terraces at each end, runs along the entire west side of the house. (ArchDaily) The caustic patterns projected onto the walls are dependent on the swimmers in the pools above, as well as breezes across the water’s surface.

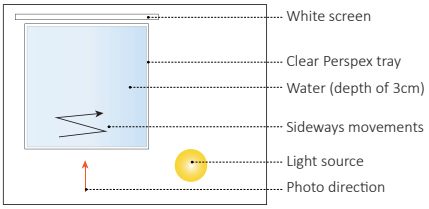
Fig.62. Caustic projection in Shaw House by Patkau Architects

CAUSTIC PROJECTION: TEST TWO

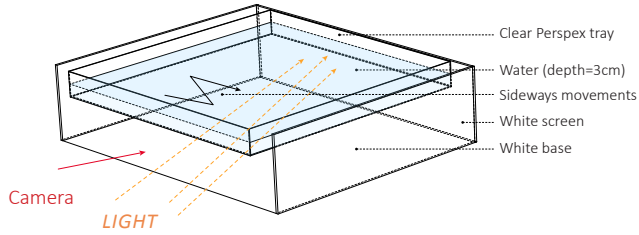
In order to show the movement of water in the space below, for the second test I have used a clear Perspex tray which will allow light to pass through it. In order to understand how the ripples travel through the water, I have used different water movements so that I can understand the resultant caustic projections from each.

Sideways Movement

SETUP PLAN:

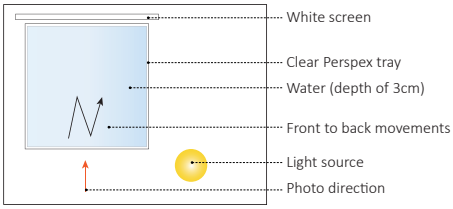


Axonometric Setup Diagram:

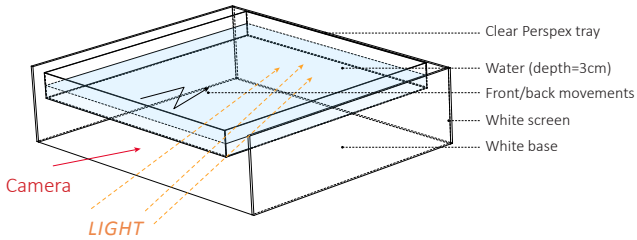


Front to Back Movement

SETUP PLAN:

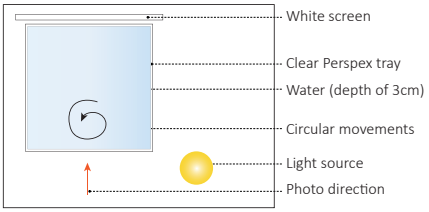


Axonometric Setup Diagram:

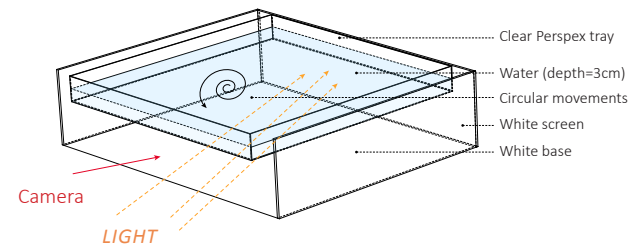


Circular Movement

SETUP PLAN:



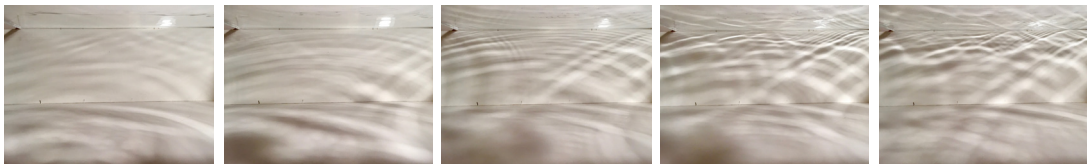
Axonometric Setup Diagram:



Law of Reflection: '*Waves will always reflect in such a way that the angle at which they approach the barrier equals the angle at which they reflect off the barrier.*' (Reflection, Refraction, and Diffraction, 2017)

Sideways Movement

Resultant Caustic Effects:



RESULTS:

The ripples form linearly, outward from the source. Once these linear ripples reach the edge of the Perspex box, they are then reflected and travel in a different direction. The crossover of the two then produce a pattern below due to the light shining through the water from above.

Front to Back Movement

Resultant Caustic Effects:

RESULTS:

Although the same principle applies, the back and forth movement creates a slightly more curved ripple, resulting in a more circular reflection being formed. Because the ripple has to travel further before it reaches a barrier, it takes longer for cross over to happen and the projected light remains linear for longer as a result.

Circular Movement

Resultant Caustic Effects:

RESULTS:

A circular motion disturbs the water more and as a result the reflected ripples and projected lines of light are wavier and less well defined. The projected light is more out of focus in this instance compared to when the water is moved in a linear manner.

DIFFRACTION

The diffracted waves pass through each other, resulting in their amplitudes adding up in space and time.

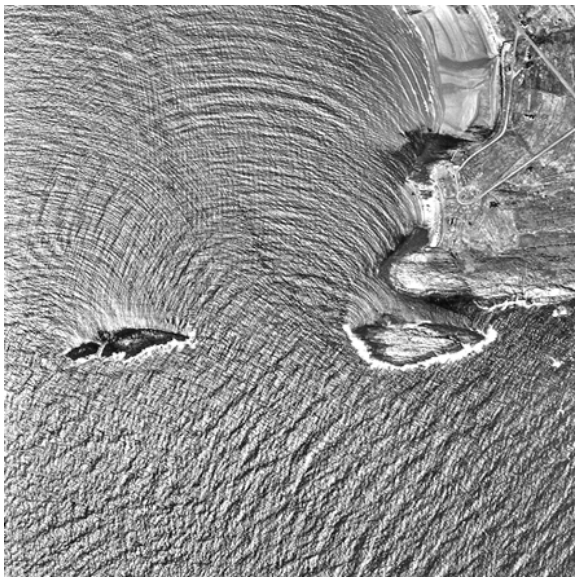
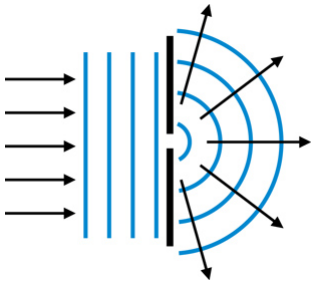


Fig.63. Aerial image showing multiple diffractions around different edges in sea waves.

Fig.64.

A gap much larger than the wavelength causes little spreading and a sharp shadow. A gap similar to the wavelength (as shown on left) causes a lot of spreading with no sharp shadow

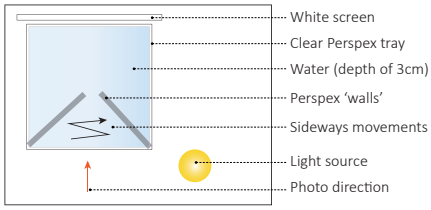


Water Diffraction: Controlling Caustic Patterns

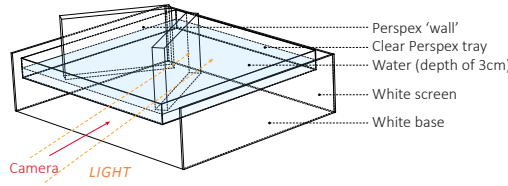
Reflection involves a change in direction of waves when they bounce off a barrier; diffraction involves a change in direction of waves as they pass through an opening or around a barrier in their path. Water waves have the ability to travel around corners, around obstacles and through openings. In order to try and control the caustics, and therefore the caustic projections better, I have tested placing objects inside the Perspex tray and have analysed the results from this.

Narrow Opening

SETUP PLAN:



Axonometric Setup Diagram:

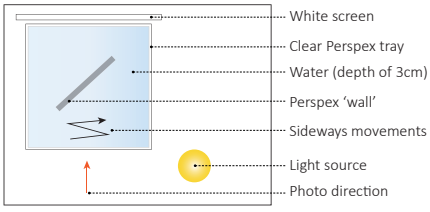


RESULTS:

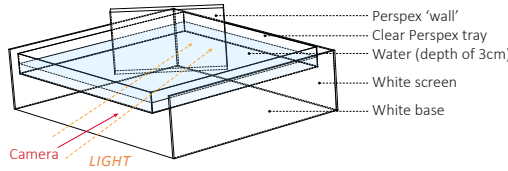
By creating ripples in the water before the small opening, there is a large amount of spreading caused (please refer to diagram on opposite page). These curved ripples, in turn, produce curved caustic patterns on the back wall. These curves reflect off the sides of the tray creating more complex shapes and forms.

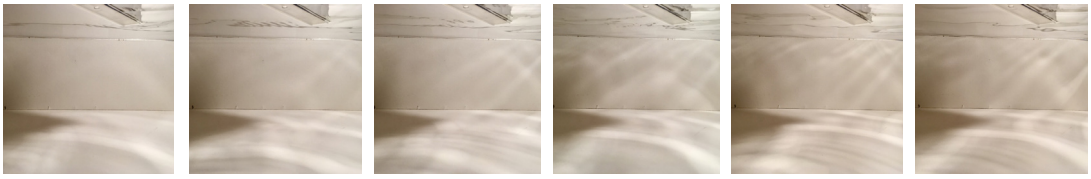
Angled Wall

SETUP PLAN:



Axonometric Setup Diagram:





RESULTS:

The diagonal wall I have created in this set up results in reflection off its surface. The ripples therefore cross over in a much more linear manner compared to the setup above. This crossover effect then reflects off the outer edges of the tray resulting in a tighter caustic pattern on the back wall. A more focused light may make these caustic projections bolder and therefore more visible.

PRECEDENCE: KALEIDOSCOPE INSTALLATION

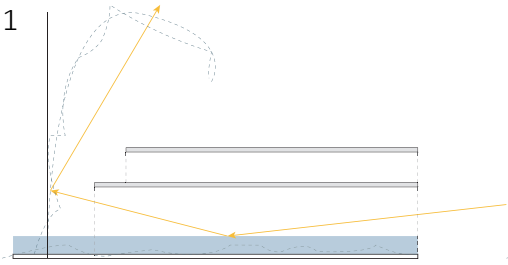
Fig.65. The light caustics created by materials needs light with precise position and direction

CAUSTIC REFLECTION: TEST FOUR

As shown in the Kaleidoscope installation precedence on the opposite page, I have tested a way of creating my own caustic effect of water using shiny reflective card. This card has been bent and folded to help create more complex reflective patterns and shapes. The back 'projection screen' wall was also tested with different types of folds and curvature in order to further enhance the reflections.

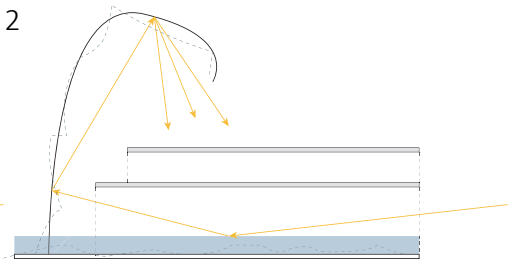
Caustic reflection testing, Set-up Sections:

1



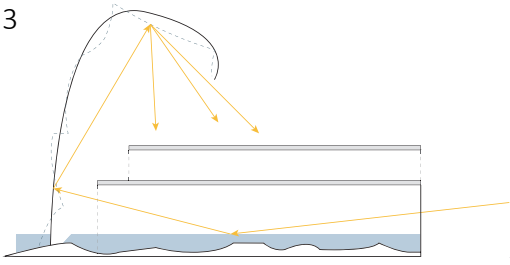
Low winter light (right hand side) reflects off waters surface and flat bottom of pool. Flat vertical wall reflects any light upwards and not captured within architecture.

2



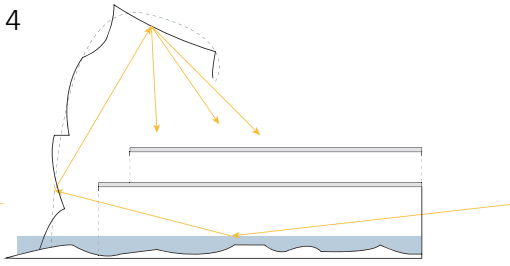
Low winter light (right hand side) reflects off waters surface and flat bottom of pool. Curved wall means that light has both a primary and secondary reflection and therefore fills space.

3

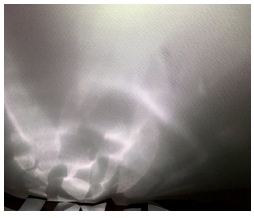


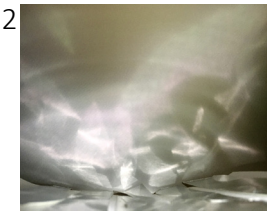
Low winter light (right hand side) reflects off waters surface and scattered further by undulating bottom of pool. Curved wall means that light has both a primary and secondary reflection and therefore fills space.

4

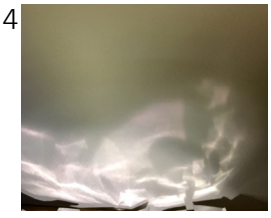


Low winter light (right hand side) reflects off waters surface and scattered further by undulating bottom of pool. Creased wall creates further patterns to be created and these are reflected into the space.

1 

2 

3 

4 

RESULTS:

From looking at the images above, there is not much variation in the caustic reflection projection, even when the curvature of the back wall is altered. Because the reflective card is static, in a similar way to the earlier caustic projection tests, there is no perception of water movement within the patterns. For the next series of tests, I would like to incorporate the use of water in order to allow for this natural motion to be visible within the space. Incorporating the movement of water into the building allows for the weather, sunlight and sounds of waves to also enter the building, allowing for presence of the outside to enter in more ways than one.

PRECEDENCE

Elizabeth Ogilvie: Out of Ice

Through her work, the Scottish environmental artist Elizabeth Ogilvie portrays the poetic dimensions of ice and water in her piece 'Out of Ice'. Here, a vast immersive installation has been created. She has experimented with ice, water and video projections in order to create a large scale piece of work which aims to represent the hidden extremes of our planet, with specific reference to global warmings effects on melting ice caps.

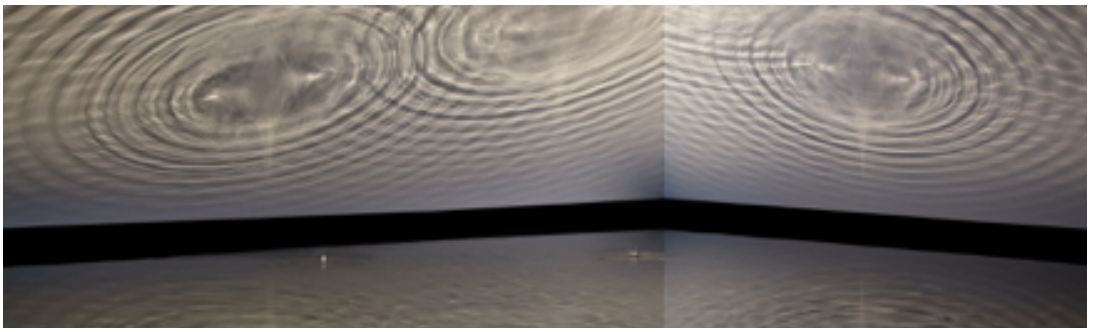


Fig.66. Elizabeth Ogilvie's installation, 'Out of Ice'

Fig.67. Elizabeth Ogilvie's 'Out of Ice'

Fig.68. Elizabeth Ogilvie's 'Out of Ice'

Rebecca Horn: 'Heart Shadows for Pessoa'

Fig.69. Rebecca Horn's Heart Shadows for Pessoa Installation

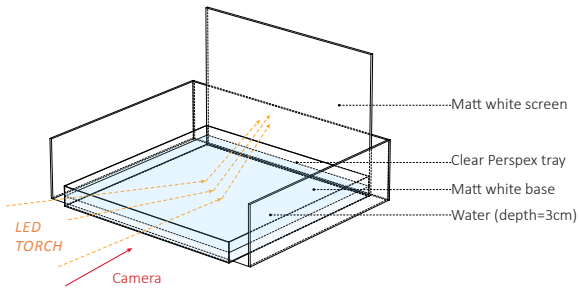
Fig.70. Rebecca Horn's Heart Shadows for Pessoa Installation

For this installation piece, Rebecca Horn has put water onto glass, which has a light shining through it from underneath. The reflection of the water in a shallow pool is reflected onto the wall behind, a recorded sound is also used and synchronized with the movement of the water, which in turn produces caustic reflections which vary in shape and size.

CAUSTIC REFLECTION LIGHT TESTS

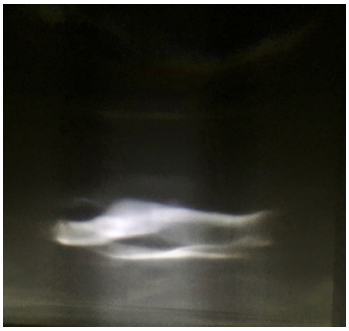
Spotlight onto water

Axonometric Setup Diagram:

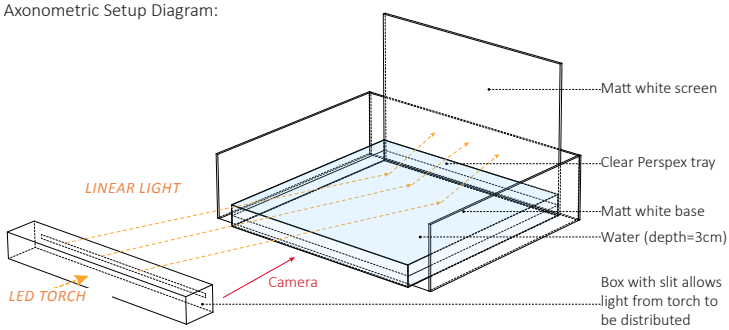


The LED light emitted by the torch is reflected by the water onto the white screen. The strong direct light means that subtle caustic patterns can't be seen as the light overpowers the projection screen. Altering the light will help to reduce the brightness.

Slit light, flat base/ wall



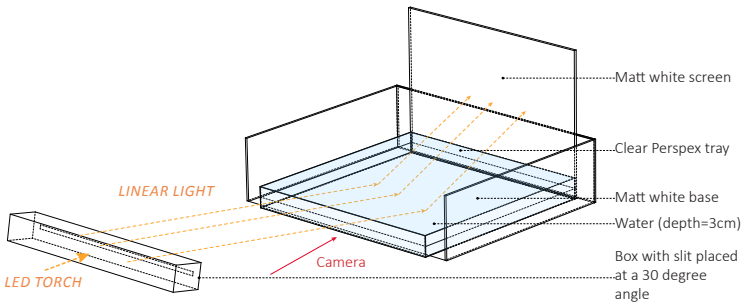
Axonometric Setup Diagram:



By creating a box with a long linear slit through the front, the light reaching the surface of the water is more controlled and not as strong. This results in a more linear reflection, in which the caustics are more visible. The patterns created are fairly faint on the screen as the light is too horizontal. The light needs to be angled so that more patterns are reflected.

Slit light, tilted base flat wall

Axonometric Setup Diagram:



Building a stand for the LED light and box with a slit, more light is being reflected off the surface of the water. This in turn has allowed for more patterns to be projected onto the dark backdrop. Due to the linear slit, these caustic reflections all appear at one level on the projection screen. Widening this gap or creating more slits would allow more caustics to be seen.

PRECEDENCE: Blue Grotto, Capri

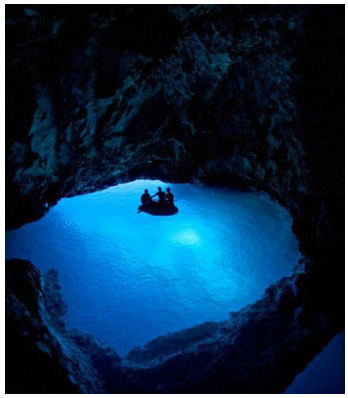


Fig.71. Photograph of the inside of the Blue Grotto

Fig.72. Photograph of the inside of the Blue Grotto cave on the island of Capri

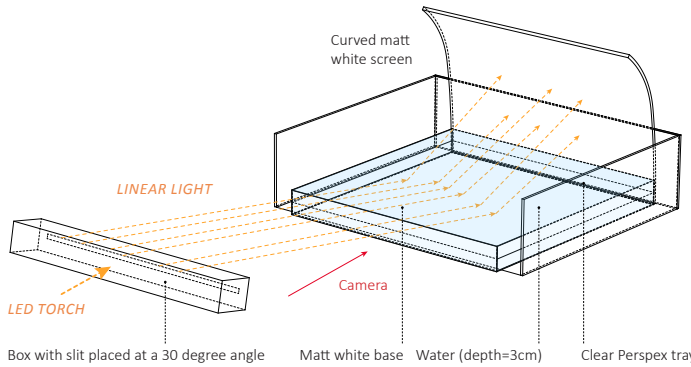
In order to distribute light within a space or onto a screen evenly with a single light source is similar to that of caves. In the case of the Blue Grotto in Capri, the light comes from two sources. One is a small hole in the cave wall, precisely at the waterline, that is a metre and half in diameter. This hole is barely large enough to admit a tiny rowboat, and is used as the entranceway.

In photographs taken from within the cave, the above-water half of this hole appears as a spot of brilliant white light. The second source of light is a second hole, with a surface area about ten times as large as the first, which lies directly below the entranceway, separated from it by a bar of rock between one and two metres thick. Much less light, per square metre, is able to enter through the lower opening, but its large size ensures that it is, in practice, the primary source of light. This creates a blue glow within the cave. It is not possible to swim in this cave as disturbing the water would ruin the effect. (Capri.com)

TEST SIX SET UP

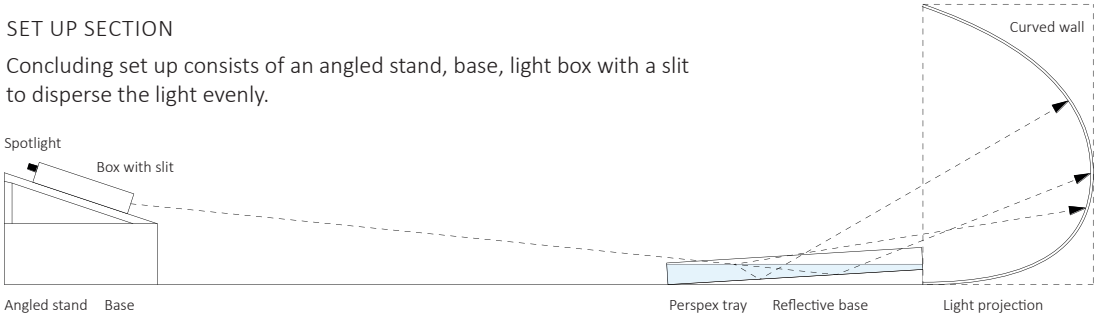
Setup Photograph:

Axonometric Setup Diagram:

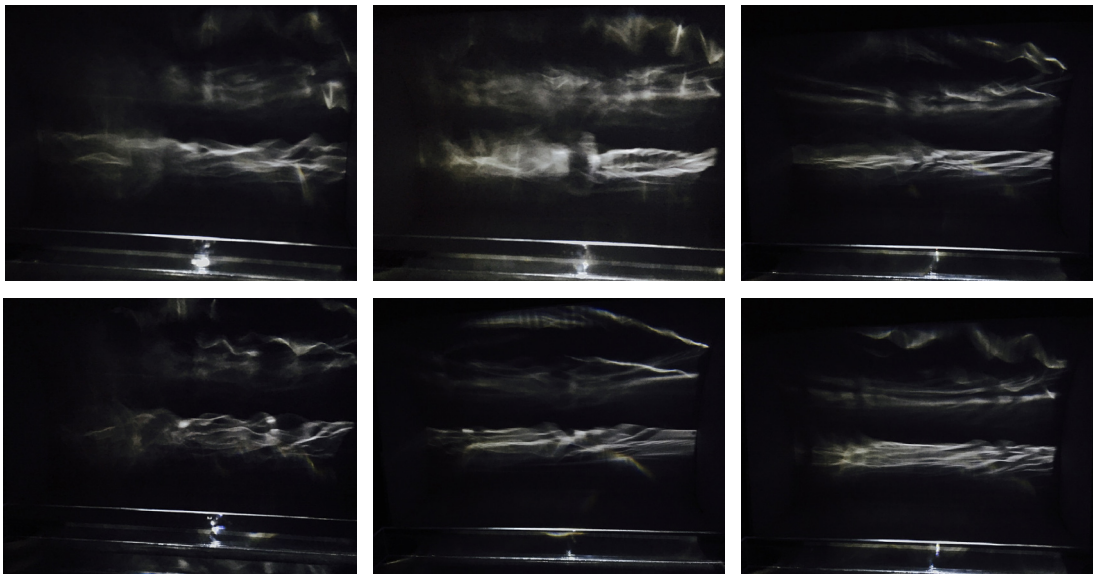


SET UP SECTION

Concluding set up consists of an angled stand, base, light box with a slit to disperse the light evenly.



PHOTOGRAPH RESULTS



RESULTS:

From the images above it is clear to see that the resultant caustic effect using the above set up results in much bolder and more well defined caustic reflections. The more focused lighting in a dark space has allowed for contrast between the 'screen' and patterns, compared to the earlier caustic projection tests.

The Perspex tray was rested at a slant with a reflective mirror surface below the shallow water. The thin slit of light is projected onto a curved, matt white screen. This duplicates the caustic patterns along the length of the wall, although the higher caustic patterns are slightly more out of focus than the lower patterns.

The combination of a matt white surface and reflective base seem to be effective materials within this set up. Through exploring materials and reflectivity values a more optimum projection surface may enhance the effect further.

The Parliament Hill Lido in Gospel Oak has a stainless steel base. Stainless steel is corrosion resistant and is therefore a highly suitable material choice for this purpose.

Fig.73. Reflections off the water at Parliament Hill Lido in Hampstead

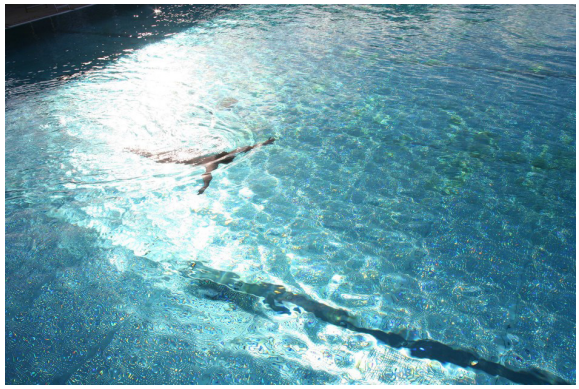


Fig.74. Caustic projections on the steel base of the Parliament Hill Lido in Hampstead

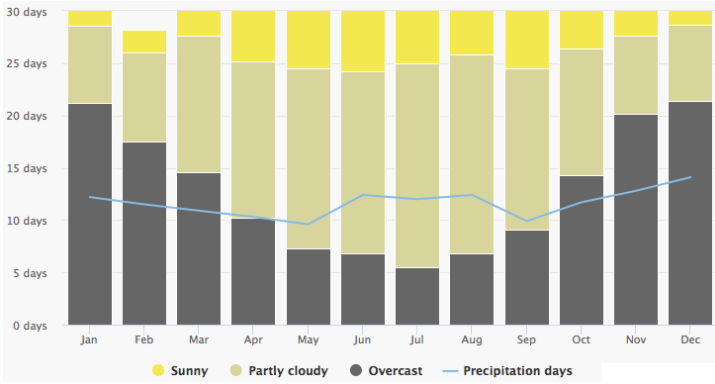


Fig.75. Graph showing cloudy, sunny and precipitation days in Stockholm, Sweden

Due to the high number of overcast days, as well as darkness during winter months in Stockholm, artificial lighting will be required to create caustic reflections at all times of year. For my next series of tests, I will therefore test materials under two light conditions: Outdoors in natural sunlight as well as indoors with LED lighting.

MATERIALITY TESTING

Matt White
(MW)

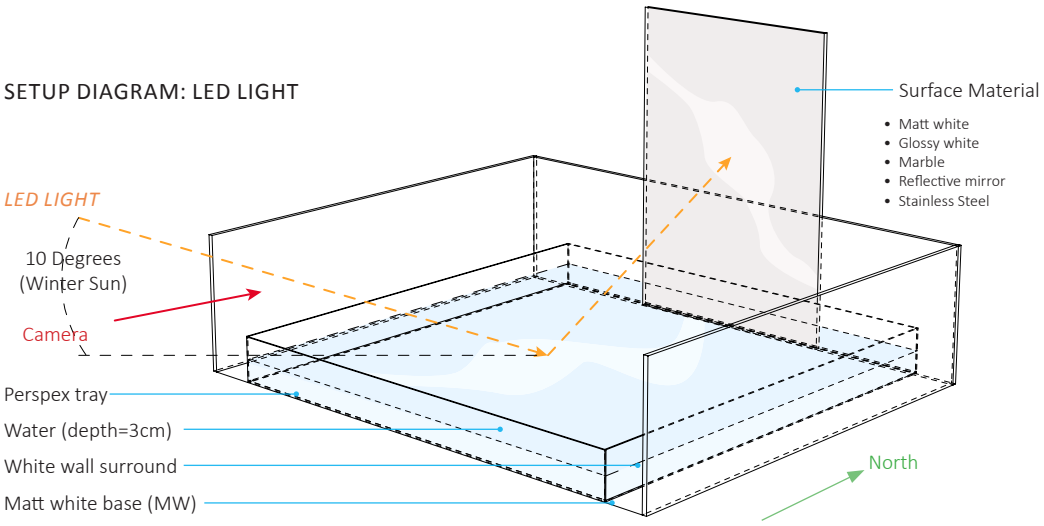
Glossy White
(GW)

Reflective Mirror
(RM)

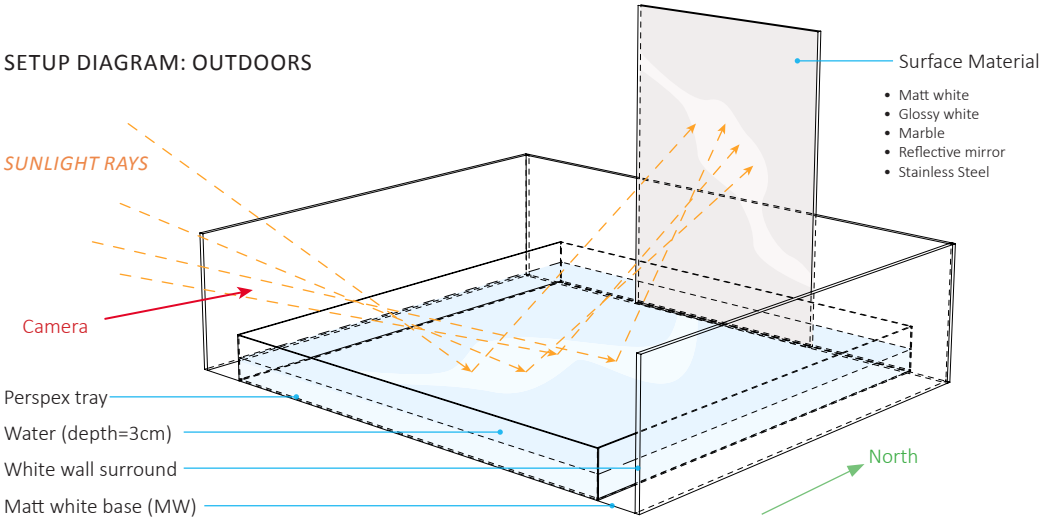
Marble
(M)

Stainless Steel
(SS)

SETUP DIAGRAM: LED LIGHT



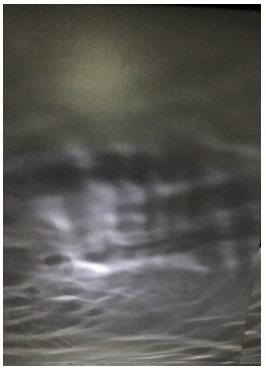
SETUP DIAGRAM: OUTDOORS



CAUSTIC REFLECTION: TEST SEVEN

INDOOR LED LIGHT RESULTS

Matt White



MW/ MW

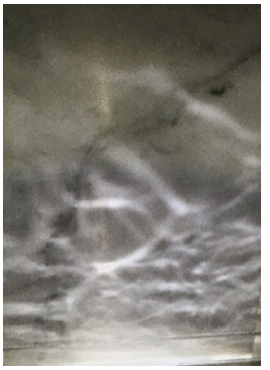
Caustics are faint and hazy on matt white, the light does not travel across the surface very well and the caustic patterns which are visible are centred around the reflection of the light source.

Glossy White

GW/ MW

The glossy tile reflects clearer, more focused patterns on its surface. The light source is visible in the reflection but this does not affect the caustics, although slightly distracts from them.

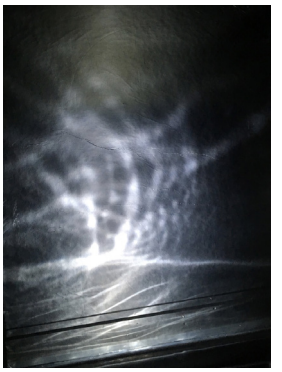
Marble



M/ MW

The vein running through the marble creates a dark contrast to the white glow of the caustic reflections. The surface is duller than the glossy surface and as a result does not focus light as well.

Stainless Steel



(SS/ MW)

The stainless steel surface, although less shiny than the glossy white surface, does reflect and focus the caustics very effectively. The darker shade of the silver backdrop causes these patterns to stand out.

Glossy White

(GW/ RM)

Stainless Steel

(SS/ RM)

The two best surfaces for reflecting the 45 degree LED light indoors were the glossy white and stainless steel. A reflective base replaced the matt white base under the Perspex tray in this set up, producing the results on the left. Here the caustics are stronger and more focused compared to a matt white base. As the stainless steel is less shiny than the glossy surface, the torch light is not visible. This creates stronger lines and patterns within the darker conditions.

OUTDOOR RESULTS

Matt White

MW/ MW

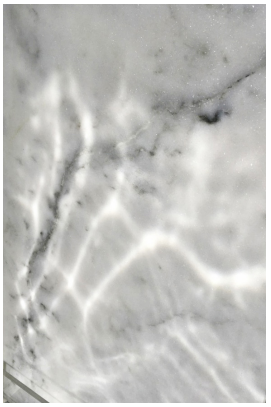
Caustics are just about visible on the matt white surface, but the faint reflected caustics blend into the white backdrop. More contrast between the material and caustic patterns is needed.

Glossy White

GW/ MW

On the glossy white tile, caustics are much more visible. Due to the higher reflectivity of the surface, even the fainter caustic patterns are visible. Glare from the sunlight fades some of these caustics.

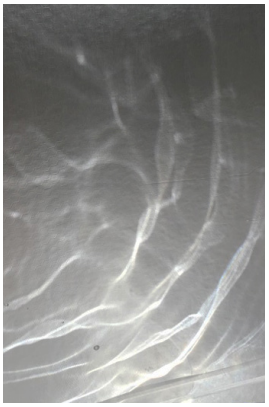
Marble



M/ MW

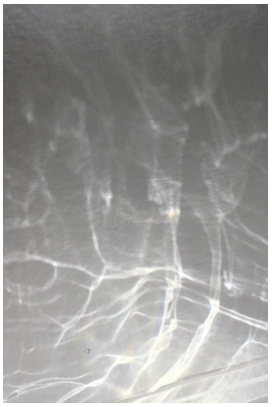
Although the marble surface does reflect caustics quite well, the darker grain of the surface distracts from the more subtle patterns that would have otherwise been visible.

Stainless Steel



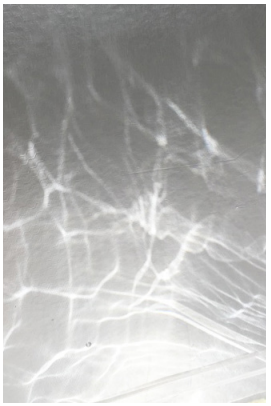
(SS/ MW)

Stainless Steel



(SS/ MW)

Stainless Steel



(SS/ MW)

Although stainless steel has a high reflectivity value, it is lower than glossy white, resulting in successful caustic reflection patterns, but without the glare that was produced by the glossy white surface. Because the backdrop of the stainless steel is not white, the milky patterns produced do not bleed into the surface and are far more visible as a result.

SETUP DIAGRAM: OUTDOORS

The previous series of tests were carried out using a matt white base. In order to try and improve the already successful caustic patterns created on the glossy white and stainless steel surfaces, a reflective base has been incorporated into the setup.

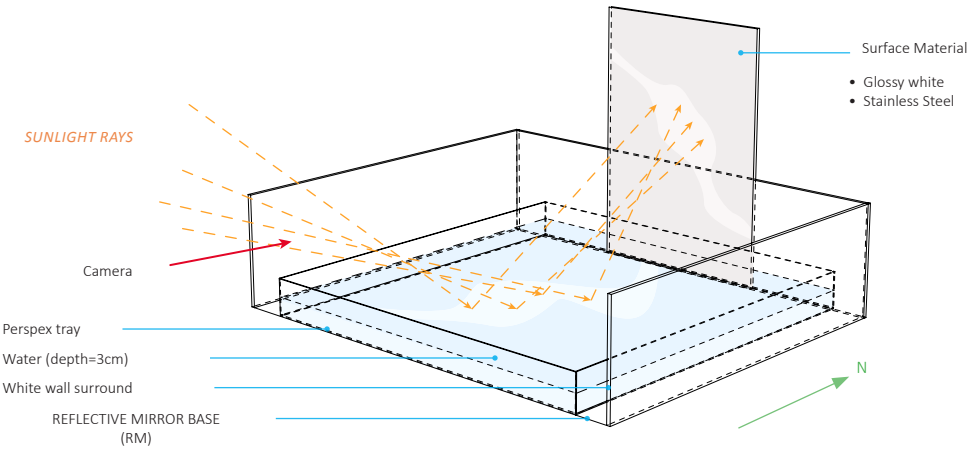


Fig.76. CLOUD COVER CONDITIONS FOR STOCKHOLM, SWEDEN


Direct full sunlight


Blue sky


Blue sky clouded horizon


Partial light cloud


Shade blue sky


Direct half shade


Light cloud

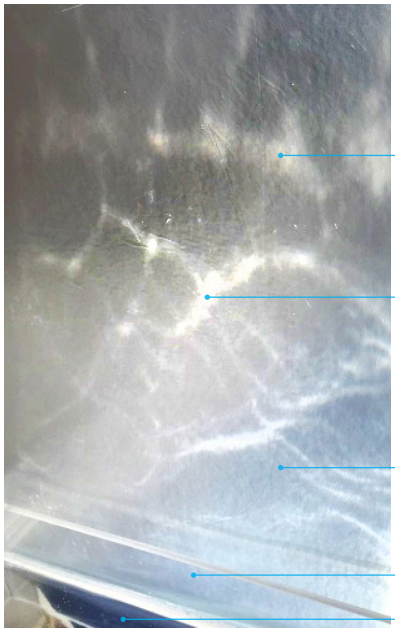

Heavy cloud

OUTDOOR SETUP RESULTS

Glossy White

GW/ RM

Stainless Steel



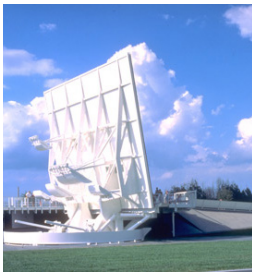
SS/ RM

The addition of a reflective base has created a higher contrast between the glossy white surface and the caustic patterns. The reflections are more focused and therefore more defined, although these remain subtle due to the white colour of the background surface these are projected onto.

The reflectance of the stainless steel alongside the mirror below the water has emphasised the caustics. Again, the white patterns stand out against the steel background compared to the white glossy tile. The reflective mirror has added a new dimension to the stainless steel surface, the blue sky has been reflected onto the sheet and has created a blue haze along the bottom. Alongside the water reflections, the weather conditions can also be seen adding a new element to the visitors experience.

Detailing the stainless steel ‘projection screen’

PRECEDENCE: The Astronauts Memorial



Located at the Kennedy Space Centre in Florida, The Astronauts Memorial commemorates the pioneering lives of the fourteen American astronauts who have died in the line of duty.

The Memorial consists of a 62 ft. high polished granite and welded steel wall that rotates and tilts to precisely track the sun through the course of each day. Attached to the back of the wall are pivoting mirrors that reflect the intensified sunlight through the letters of the astronauts’ names.

Fig.77. The Astronauts Memorial

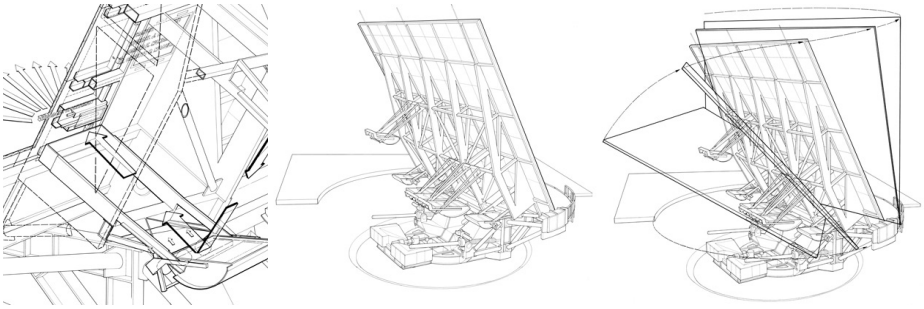


Fig.78. The Astronauts Memorial; series of diagrams showing rotating movement of wall

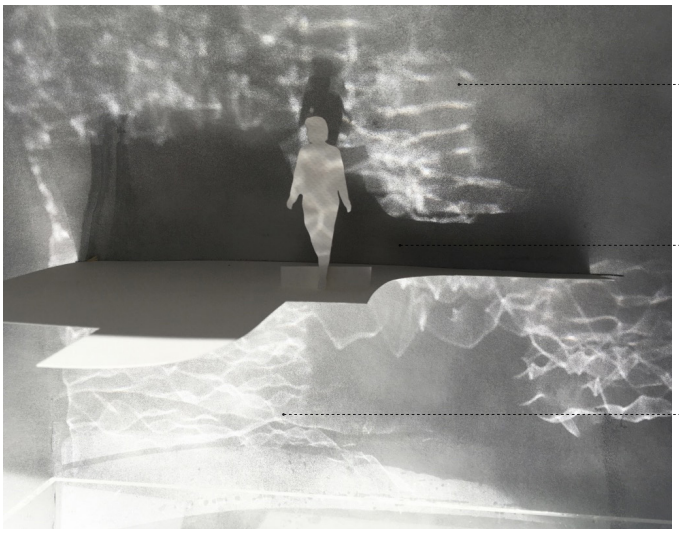
In order to make sure caustics are able to be reflected at all times of day during summer and winter within my proposed scheme, the orientation of the stainless steel ‘projection screen’ walls will need to vary. Some of these walls can be static and dedicated to light at a particular time of day and month, but other walls could pivot in order to follow the path of the sun.

Due to the extreme seasons and weather in Stockholm, the properties of stainless steel make it an extremely suitable choice of material. Stainless steel does not readily corrode, rust or stain with water and because of the durability of the material, the ‘projection walls’ will retain their original appearance, and therefore reflectance over a long period of time, with very little maintenance being required.

MATERIALITY TESTING

In the previous series of tests, I have been looking at a flat 'projection screen' wall for the caustic patterns. Within this test I have begun to bring in floors and walls in order to develop how this caustic effect can be brought into the architectural proposal successfully. Materiality for the projection screen have been tested, and now walls and floors need to be considered so that the delicate caustic patterns are not interrupted within the scheme.

SOLID FLOOR SET UP

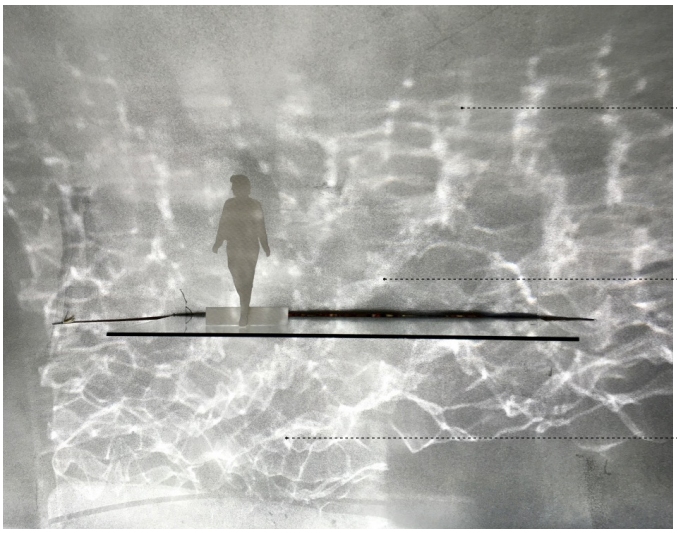


Stainless steel wall enhances caustic patterns created by sunlight reflecting off the water below.

As the reflected light is entering from below, the solid floor results in shadows being produced on the stainless steel backdrop. This results in the caustic patterns being lost.

The caustic network patterns below are not visible to the visitor due to the solid wall blocking the line of sight

TRANSPARENT FLOOR SET UP



Stainless steel wall enhances caustic patterns created by sunlight reflecting off the water below. The curved wall helps to keep these patterns in focus

The transparent glass floor allows for the caustic network of patterns to be carried up through the floor, directly onto the stainless steel backdrop

The tighter reflected caustic patterns below the floor are now visible to the visitor due to the transparent surface below their feet

DESIGN PR0POSAL: MODELLING

The area within my SAD Landscape Masterplan I will be focusing on is the relaxation zone within the 'Exercise Landscape'. Here, the architecture is surrounded by water from the bay as well as swimming pools. The water will therefore be disturbed by wind and boats, as well as swimmers. I will be tying together all of the elements I have looked at during my testing and analysis to create a relaxing zone, where both sufferers of seasonal depression and people wishing to escape the city, can enjoy during all times of year.

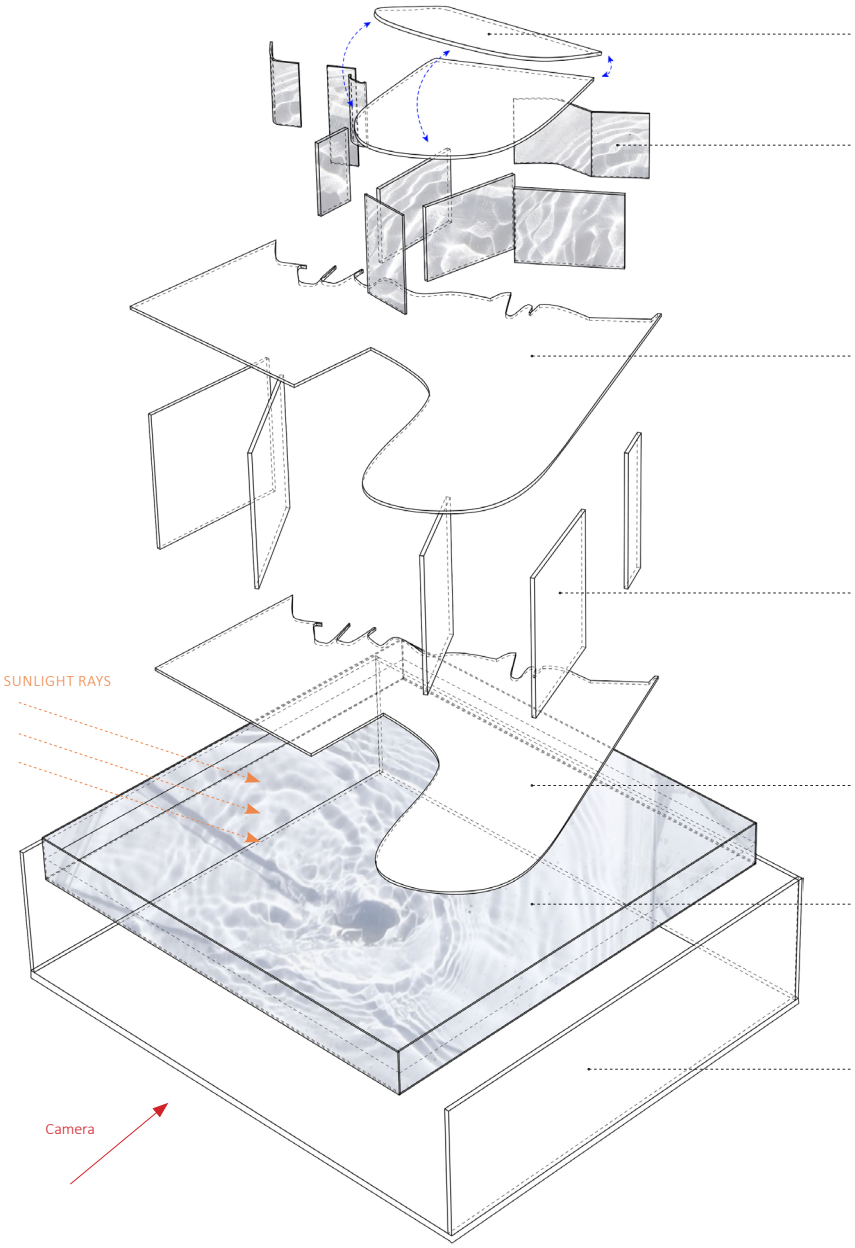
ELEMENTS TO BE INCORPORATED INTO THE DESIGN HAVING ANALYSED TESTING RESULTS:

- Caustic Projection - swimming pools on roof
- Boundaries in water to create diffraction and tighter caustics
- Matt white base - to avoid reflective glare
- Artificial lighting to be used alongside natural sunlight
- Stainless Steel 'projection walls' to be curved and orientated at different angles in order to capture sunlight
- Transparent floors and walls to prevent shadows being cast, this will make the caustic network patterns visible from all directions

Fig.79. Modelling the relaxation zone within the Exercise Landscape, Stockholm, Sweden

SETUP DIAGRAM: OUTDOORS

Axonometric diagram showing the elements to be included within the design



Rotating roof moves accordingly to follow the angle of the sun throughout the year

South facing stainless steel walls reflect caustic patterns created by water below.

The transparent structural laminated glass floor allows for the caustic network of patterns to be carried up through the floor, directly onto the stainless steel backdrop

Transparent structural laminated glass walls allow light to travel to the back of the design proposal spa/ relaxation area. These walls also result in waves being diffracted which leads to tighter caustic networks being created

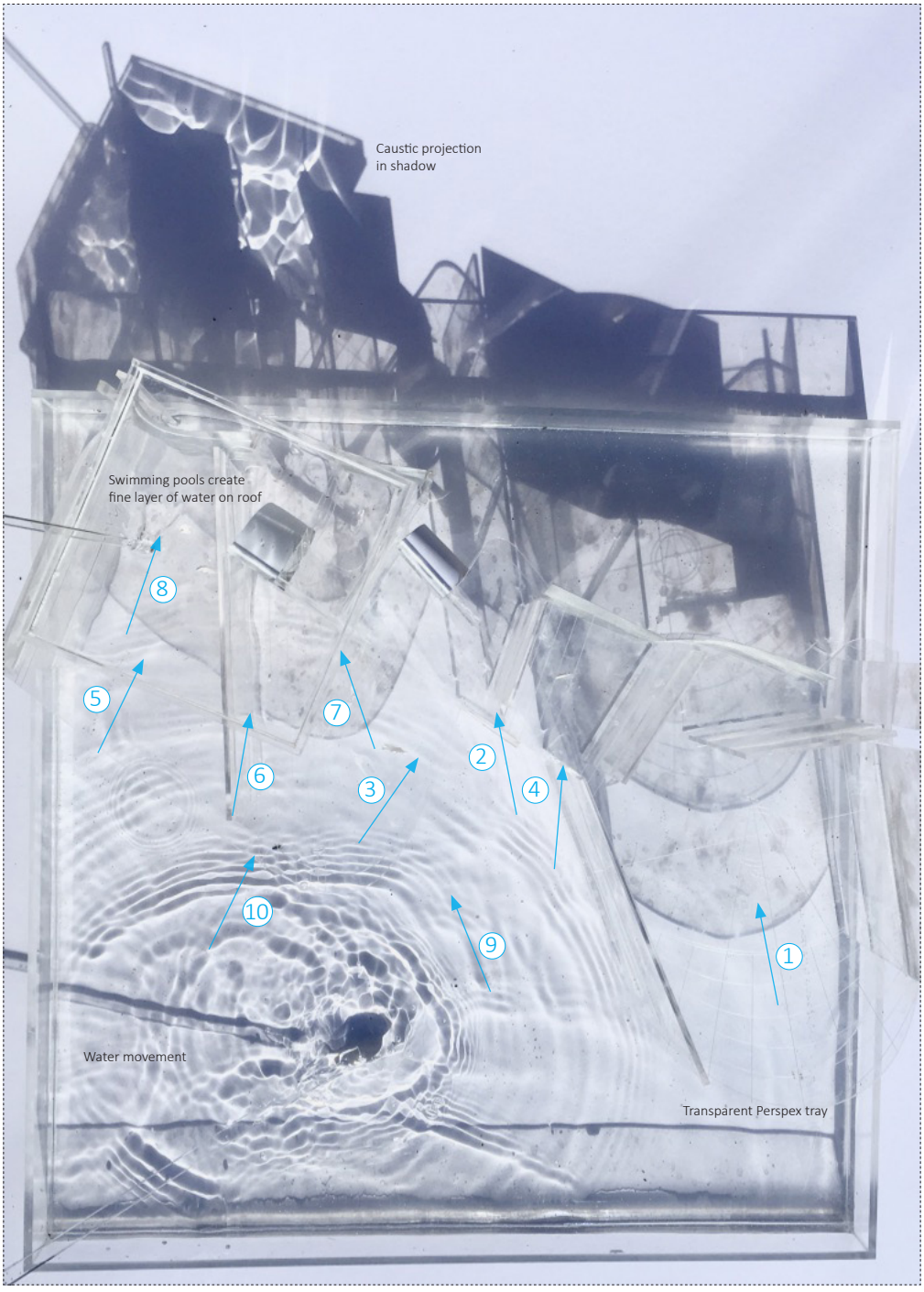
The transparent structural laminated glass floor allows for the caustic network of patterns to be carried up through the floor, directly onto the stainless steel backdrop

Water movement causes different patterned reflections

Matt white base below water results in more reflection but less glare than a reflective surface would provide

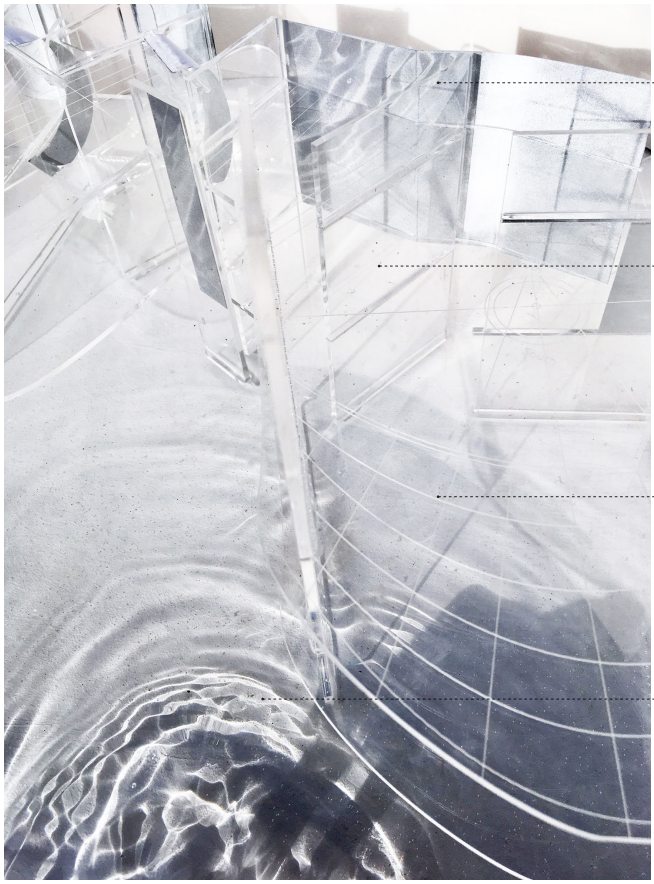
FINAL MODEL: Outdoor Plan View

Annotated key image showing caustic projection and caustic reflection within the proposed scheme. Each annotation shows the direction in which each detail photo, shown on the following pages, has been taken.



FINAL MODEL: Outdoor Detail Views

Detail images of model showing caustic projection patterns on proposed stainless steel walls. The transparent floors and walls in the proposal allow for light to be reflected in many directions and therefore the water reflections are not blocked or inhibited.



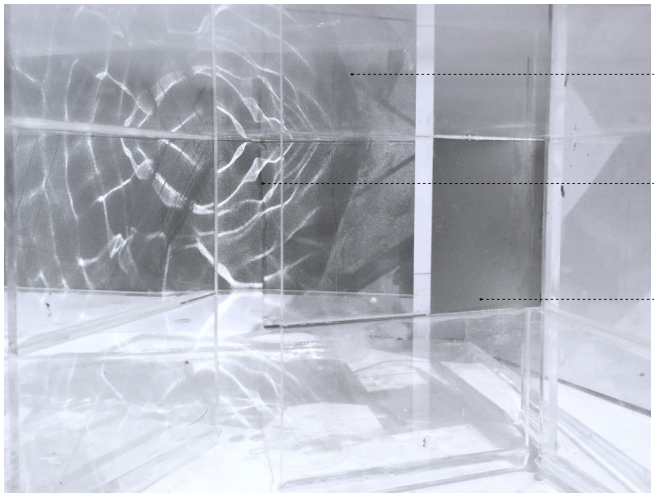
1 DETAIL VIEW 1

Stainless steel wall reflects caustic patterns created by water below.

Transparent glass walls allow light to travel to back of design proposal spa/ relaxation area

Transparent structural glass walls and floors allow light and therefore caustic reflections to pass through

Water movement causes different patterned reflections



2 DETAIL VIEW 2

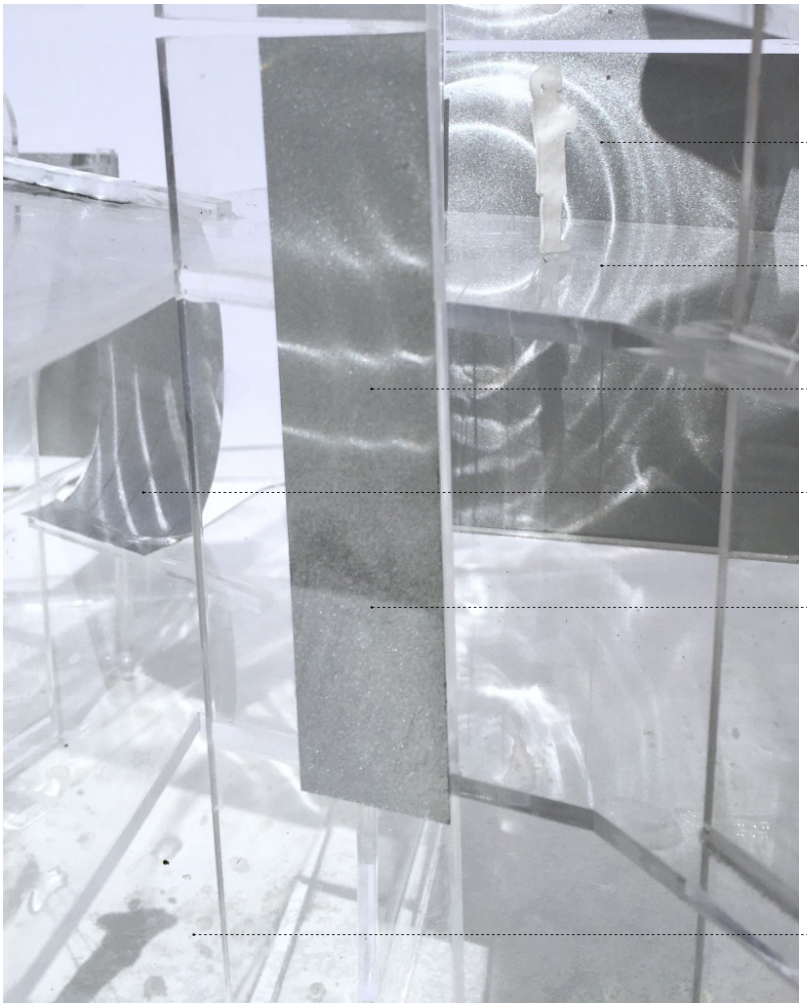
Stainless steel wall behind transparent glass structural walls

Caustic reflections on stainless steel 'projection wall' are duplicated in the reflections on the glass walls, further enhancing the effect created for the user within the space

Stainless steel walls are higher than the waters' surface in order to 'catch' the caustic reflections from natural daylight

FINAL MODEL: Outdoor Detail Views

Because of the glass structure within the building, I have included both internal and external stainless steel walls. The solid external walls on the front facade of the building need to be narrow so that the light can still enter the rear walls and does not cast a shadow over this.



3 DETAIL VIEW 3

Stainless steel wall behind transparent glass structural walls

Glass floor to allow visibility at all angles from inside

Narrow strip of stainless steel on the facade of the building

Curved stainless steel walls capture reflections when the sun is lower in the sky, particularly during winter months

Variation in height and angle of the projection walls so that as much light can be captured throughout the year

Water movement below structure causes different patterned reflections

FINAL MODEL: Outdoor Detail Views

The ceilings and floors within the space allows for further reflection of light and caustic network patterns. Although the walls and floors are clear, the sharp reflections create barriers between the spaces and therefore more privacy.

4 DETAIL VIEW 4

Transparent glass ceiling structure

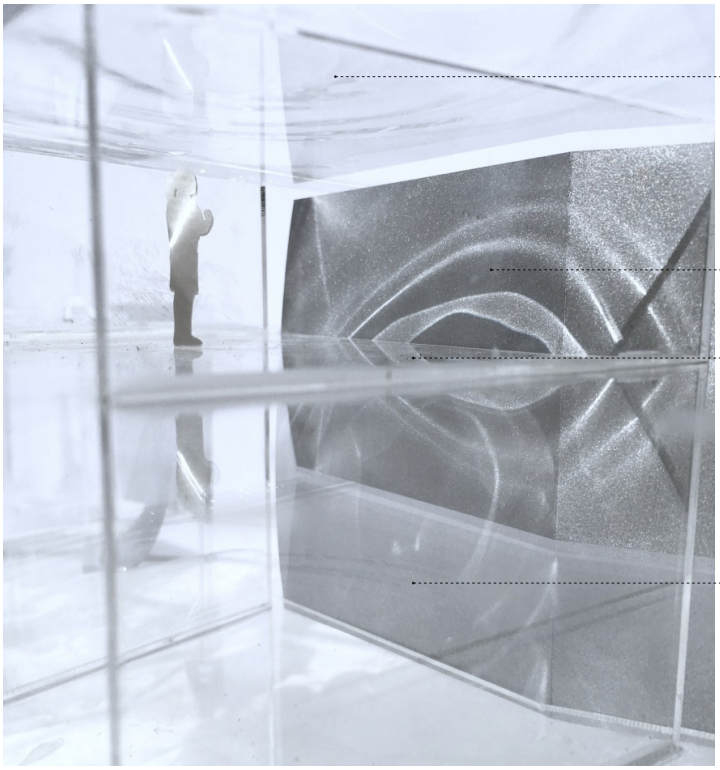
Transparent ceiling has a shiny surface which allows for reflection in all directions

Stainless steel projection wall behind transparent glass structural walls reflects caustic patterns into the space

Transparent glass floors has a shiny surface which allows for reflection in all directions

Water movement below structure causes different patterned reflections

FINAL MODEL: Outdoor Detail Views



5 DETAIL VIEW 5

Transparent ceiling has a shiny surface which allows for reflection in all directions

Stainless steel wall behind transparent glass structural walls

Transparent glass floors has a shiny surface which allows for reflection in all directions

Water movement below structure causes different patterned reflections

6 DETAIL VIEW 6

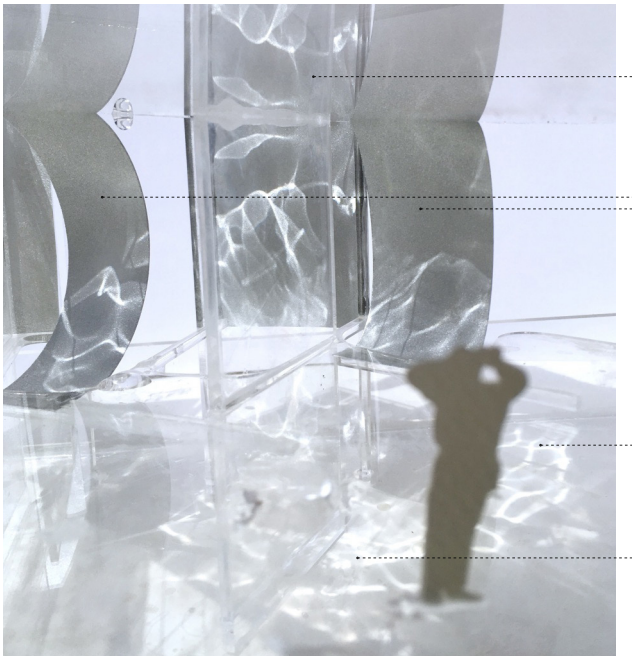
Transparent ceiling has a shiny surface which allows for reflection in all directions

Stainless steel wall behind transparent glass walls

Curved stainless steel walls capture reflections when the sun is lower in the sky, particularly during winter months

Water movement below structure causes different patterned reflections

FINAL MODEL: Outdoor Detail Views



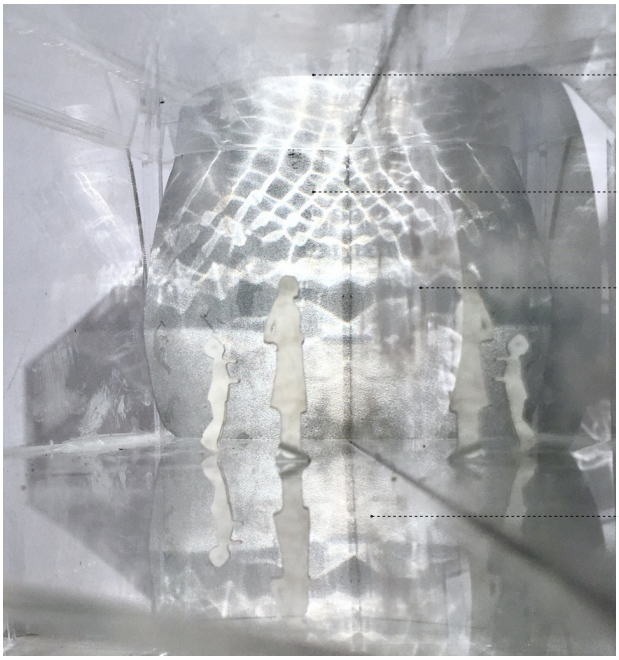
7 DETAIL VIEW 7

Stainless steel wall behind transparent glass walls

Curved stainless steel walls capture reflections when the sun is lower in the sky, particularly during winter months

Transparent glass floors has a shiny surface which allows for reflection in all directions

Water movement below structure causes different patterned reflections



8 DETAIL VIEW 8

Transparent ceiling has a shiny surface which allows for reflection in all directions

Stainless steel wall behind transparent glass structural walls

Reflections off glass walls create barriers between the spaces and therefore more privacy.

Transparent glass floors has a shiny surface which allows for reflection in all directions

Structural Glass Technology

In order to reduce the seams and therefore resultant shadows within the structure, I have looked into precedence that have developed ways of fabricating larger glass panels along with a seamless construction.

PRECEDENCE: Apple 5th Avenue Mark 2

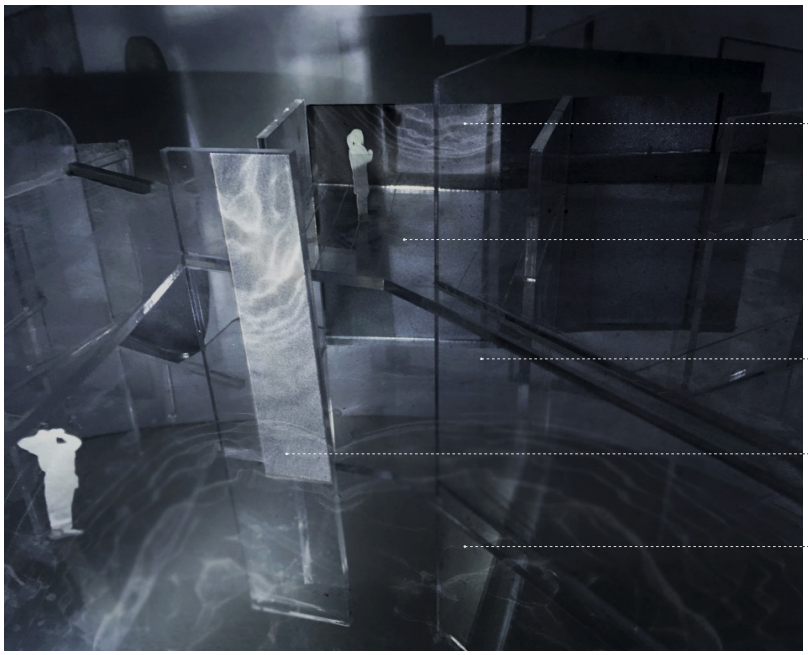
Fig.80. Apple 5th Avenue Mark 2, New York

Fig.81. Apple 5th Avenue Mark 2, New York

For this project the team developed a number of design, fabrication and connection technologies as a result of a drive to evolve the language of glass within the Apple retail environment. The second Cube (shown above) was completed in 2011 and was an opportunity to collate the latest in structural glass design and fabrication in order to enhance its transparency. (Eckersley O'Callaghan)

FINAL MODEL: Indoor Detail Views

On this page there are detail images of the model showing caustic projection patterns, using LED lighting in order to resemble the use of artificial lighting during darker days in winter. In comparison to the outdoor tests, the artificial light does not create such crisp caustic network patterns on the stainless steel facades. The light has been placed at an angle of ten degrees in order to resemble the lowest the sun reaches in the sky. This setup is therefore showing the lowest light conditions within Stockholm. Further testing with different light sources and focusing the incoming light beam may result in crisper patterns being produced.



9 DETAIL VIEW 9

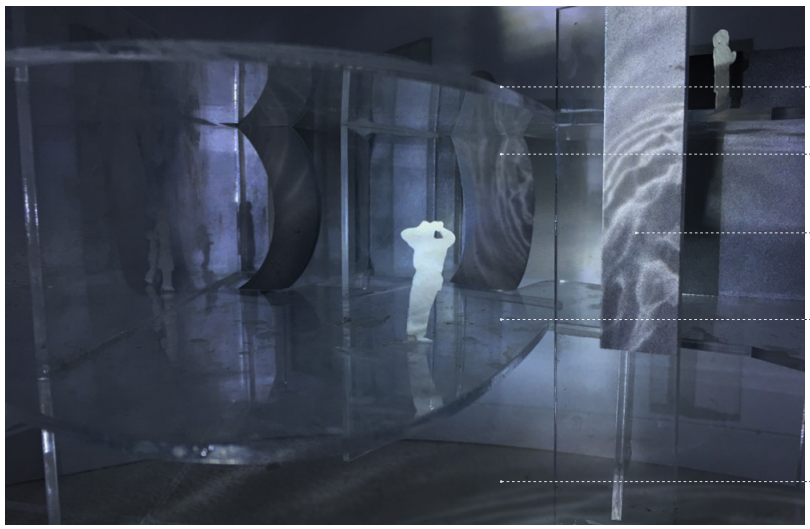
Stainless steel wall behind transparent perspex walls

Transparent glass floors do not reflect the caustic patterns as well with artificial light compared to natural sunlight

Structural laminated glass is used for the floors and structural walls

Stainless steel wall reflects caustics more faintly under artificial light, but the effects can still be seen

Transparent walls do not reflect the caustic patterns as well with artificial light compared to natural sunlight



10 DETAIL VIEW 10

Structural laminated glass is used for the floors and structural walls

Stainless steel curved wall behind transparent perspex walls captures low angle light reflections

Stainless steel wall reflects caustics more faintly under artificial light, but the effects can still be seen

Transparent glass floors do not reflect the caustic patterns as well with artificial light compared to natural sunlight

Water movement below structure causes different patterned reflections

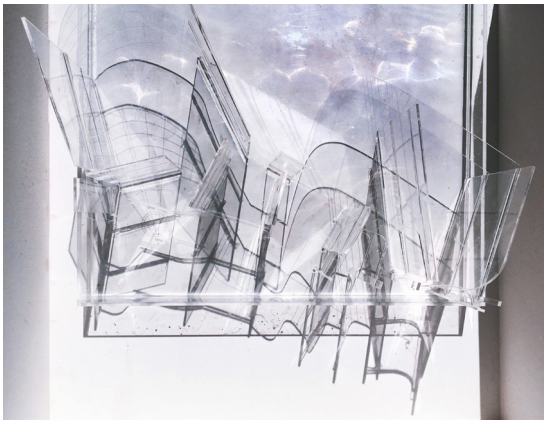


Fig.82. Model in plan view on summers day

We are living in a world where we are spending more and more time indoors, as a result, there is very little connection to nature within cities. Stockholm does have a vast amount of green space and water, but from the number of cases of Seasonal Affective Disorder affecting the population, it is evident that natural daylight, as well as nature, is required to significantly improve well-being. It is important that we bring light and nature into our architecture, even if this is done in subtle ways, such as through reflection. A seemingly simple and sensitive intervention such as this can make a huge impact on people's health and happiness at any time of year, enabling for a better connection with the surrounding environment to be developed. This is particularly important during winter months when short days and long nights can lead to depression.

We can look at nature, art and architecture precedence in order to develop our understanding and appreciation of such interventions. From this, concepts and techniques carried out through testing will be improved further. The contextual background research carried out for Scandinavia, followed by physical testing, has allowed me to gain a much greater awareness of the unique context in which I was working with. This notion and exploration, alongside examining precedence that relate to these key themes, have allowed for a distinctive type of reflection to be incorporated into my testing. This has resulted in a unique architectural proposal that works within its contextual background.

Developing architecture using physical test studies allows for the results to be seen directly, which are then able to be updated and built upon accordingly. The tests and analysis carried out have shown how optimum conditions for caustic patterns can be created, such as through materiality, which has in turn, enabled caustic network patterns to be emphasised. Through the use of natural daylight and artificial lighting, comparisons can be made in order to develop a design which works all year round, even in the Nordic winter conditions. When developing architecture for a specific contextual setting such as Stockholm, it is vital that testing and analysis is carried out on smaller scales, before transferring to larger scale tests. This ensures an effective outcome is possible in the given limited conditions.

The series of tests and analysis within this report have all been made at small scales compared to the vast landscape proposal I wish to resolve. In order to create the optimum conditions for caustic patterns within the construction, moving the tests up to larger scales, at this point, would be hugely beneficial. Further testing with a wider variety of textures, as well as additional angles of lighting would be advantageous, in order to ensure optimum results can be generated on site. After this has been developed, the resultant architecture will improve further in terms of complexity and effectiveness.

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