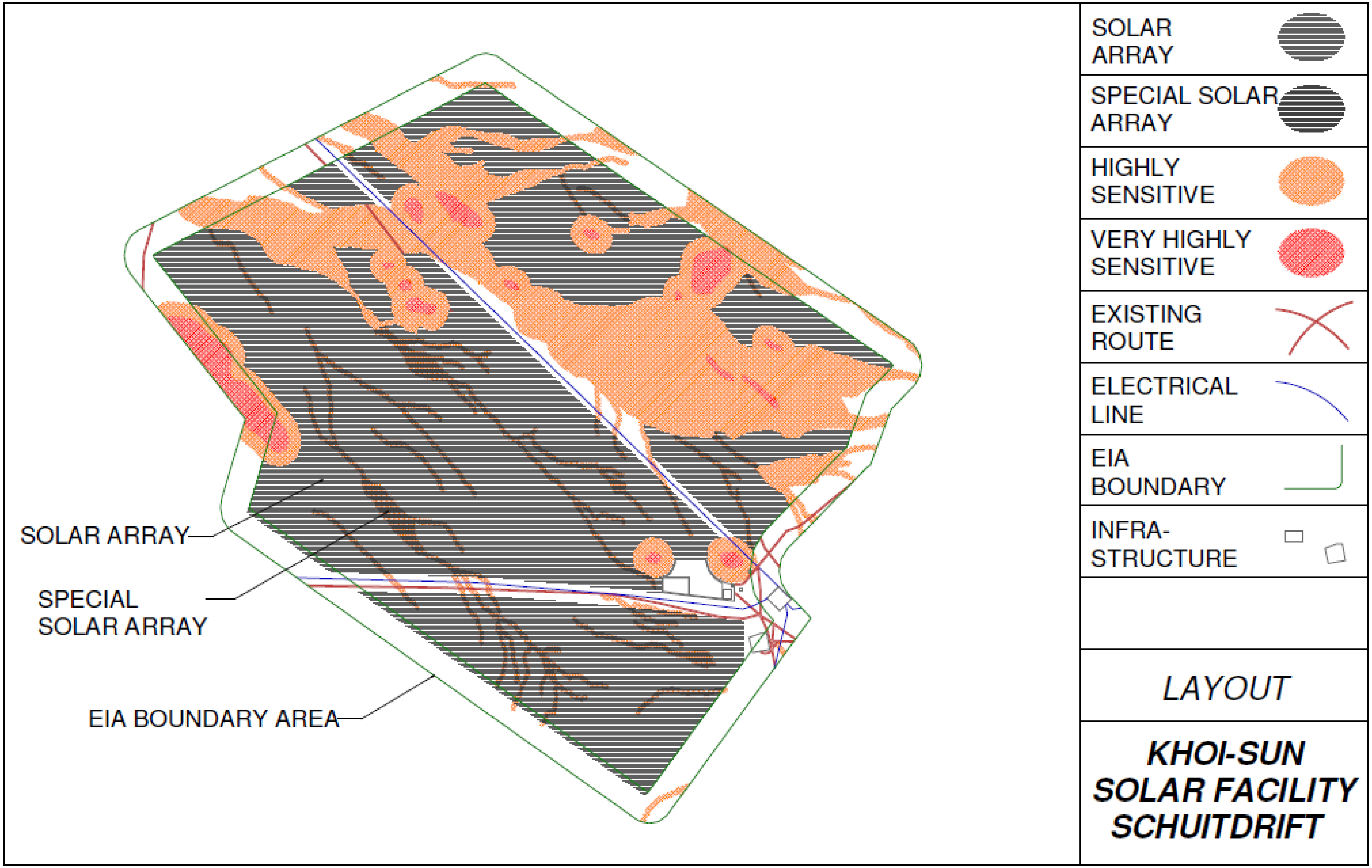
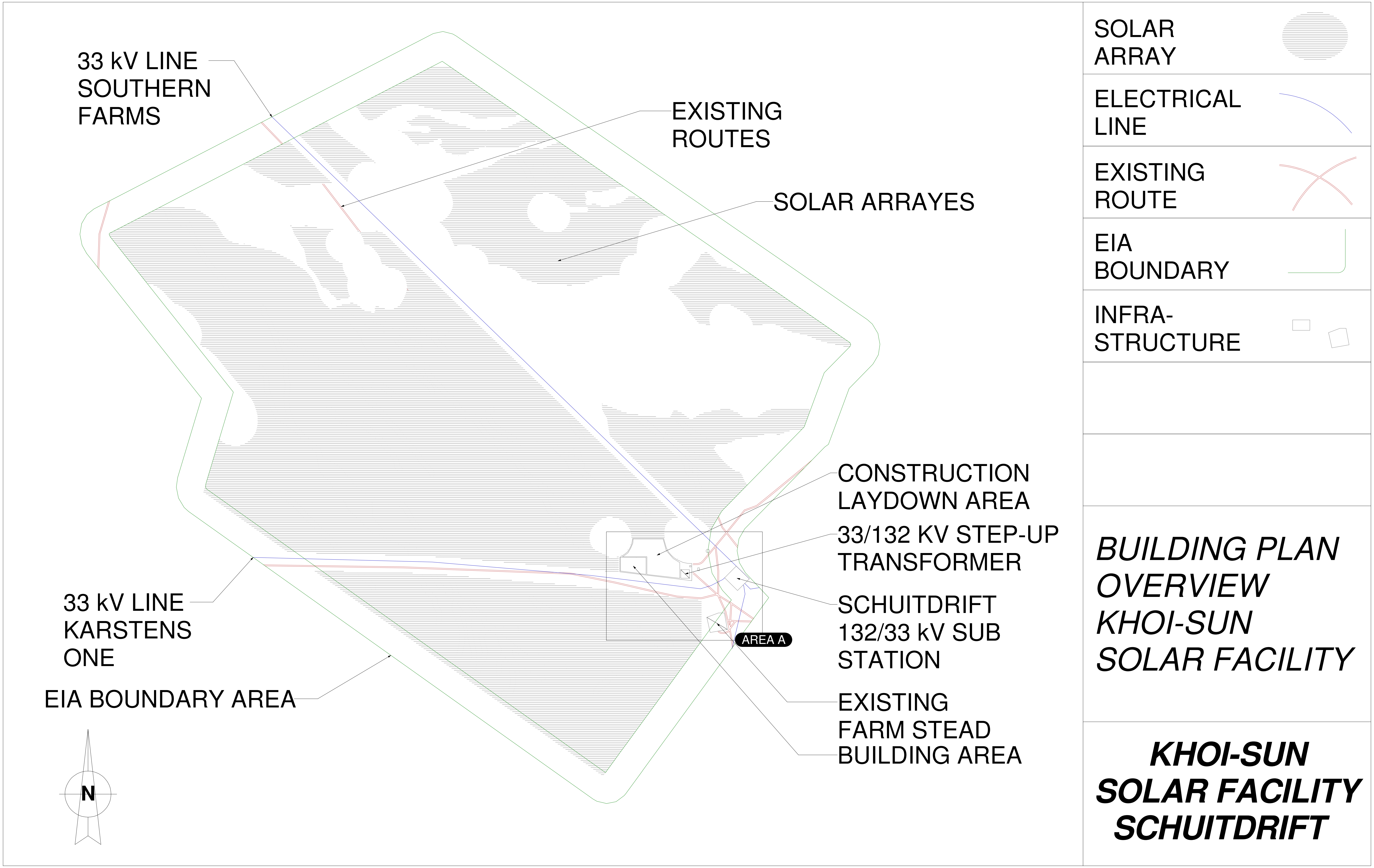
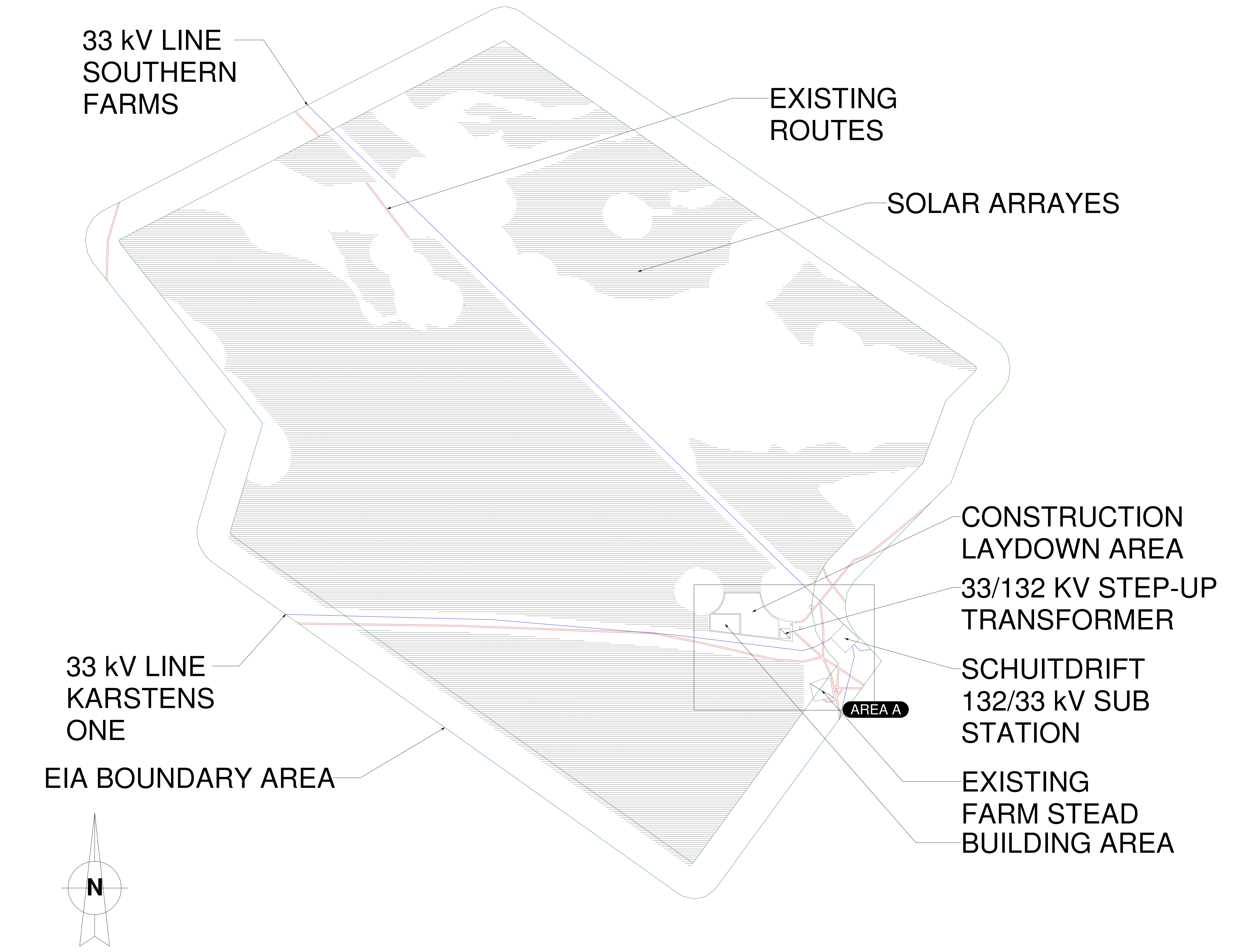
Preferred / Mitigated Layout (Alternative 4)





BUILDING PLAN OVERVIEW KHOI-SUN SOLAR FACILITY

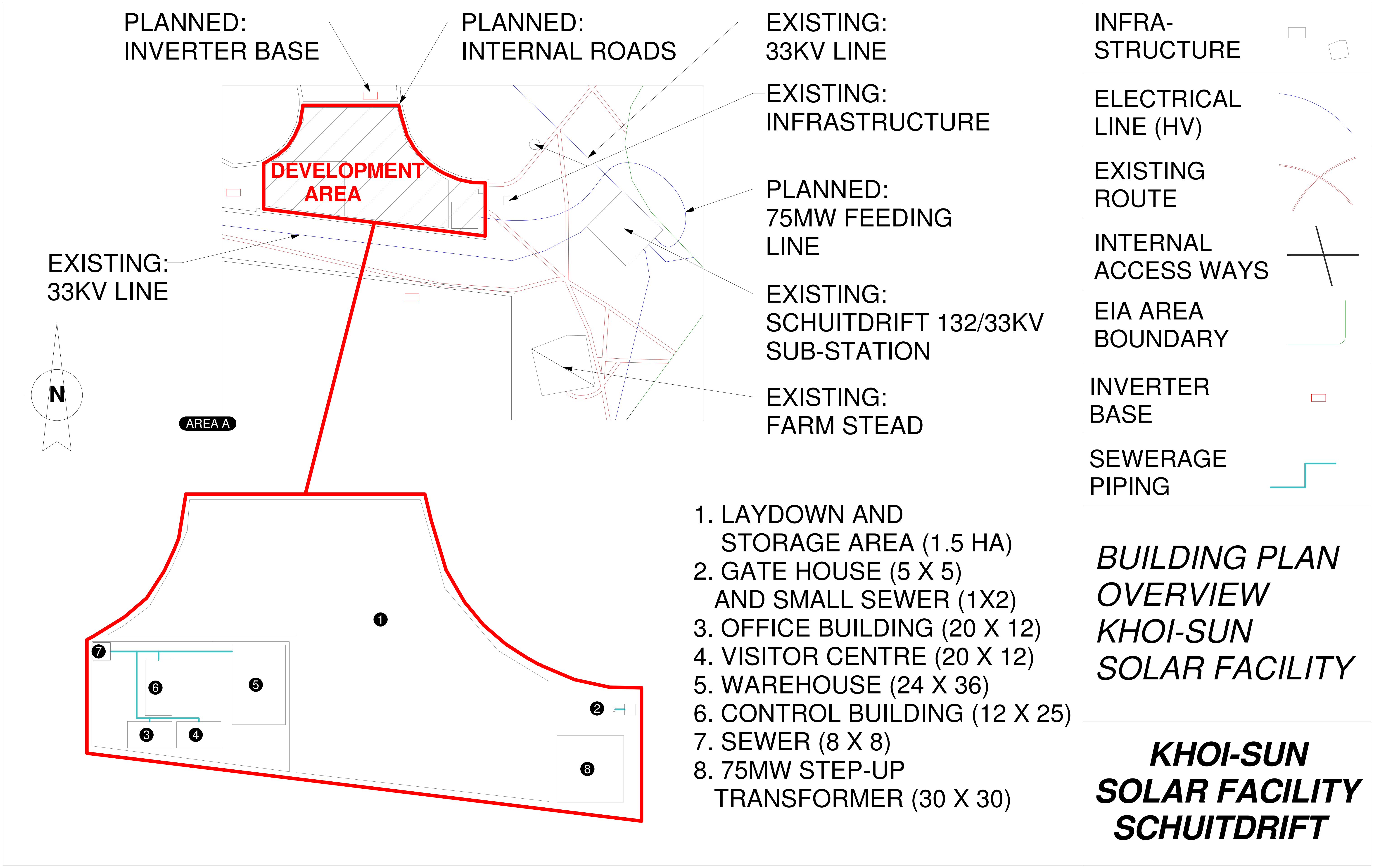
KHOI-SUN SOLAR FACILITY SCHUITDRIFT

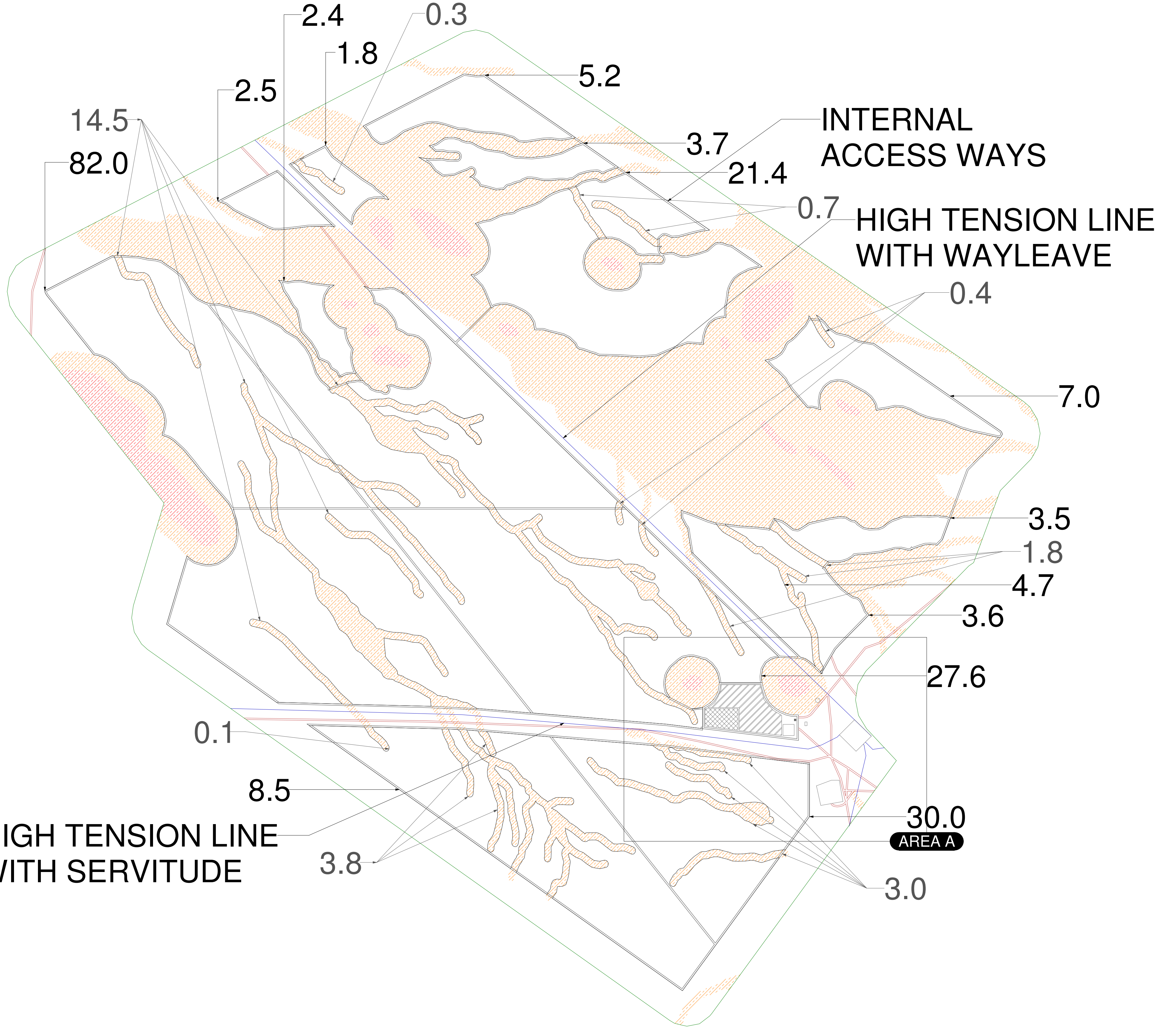


SOLAR ARRAY	
ELECTRICAL LINE	
EXISTING ROUTE	
EIA BOUNDARY	
INFRA-STRUCTURE	

BUILDING PLAN OVERVIEW KHOI-SUN SOLAR FACILITY

KHOI-SUN SOLAR FACILITY SCHUITDRIFT

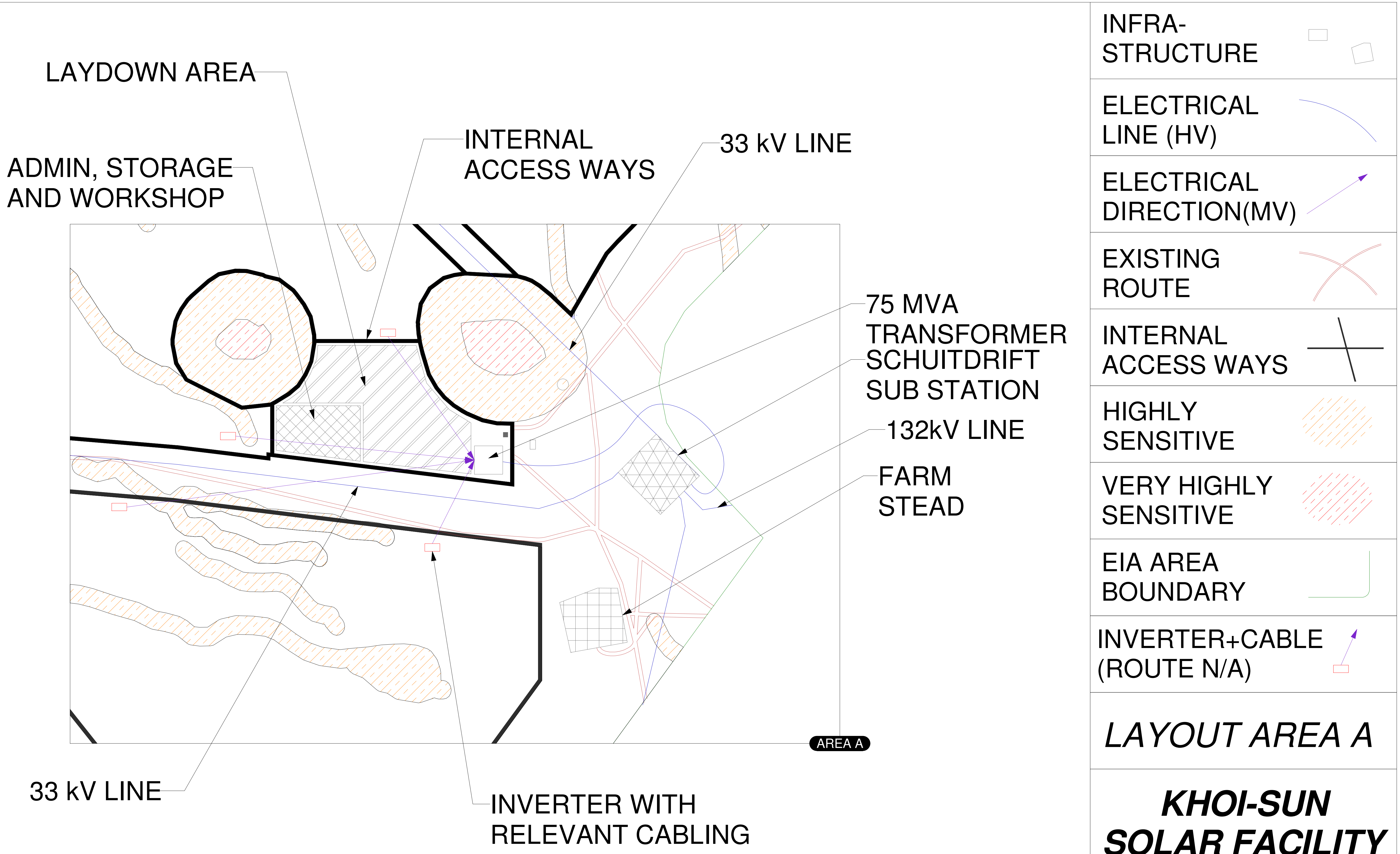

PLANNED: INVERTER BASE
PLANNED: INTERNAL ROADS
EXISTING: 33KV LINE
EXISTING: INFRASTRUCTURE
PLANNED: 75MW FEEDING LINE
EXISTING: SCHUITDRIFT 132/33KV SUB-STATION
EXISTING: FARM STEAD
EXISTING: 33KV LINE
DEVELOPMENT AREA
N
AREA A
1
2
3
4
5
6
7
8
1. LAYDOWN AND STORAGE AREA (1.5 HA)
2. GATE HOUSE (5 X 5) AND SMALL SEWER (1X2)
3. OFFICE BUILDING (20 X 12)
4. VISITOR CENTRE (20 X 12)
5. WAREHOUSE (24 X 36)
6. CONTROL BUILDING (12 X 25)
7. SEWER (8 X 8)
8. 75MW STEP-UP TRANSFORMER (30 X 30)
INFRA-STRUCTURE
ELECTRICAL LINE (HV)
EXISTING ROUTE
INTERNAL ACCESS WAYS
EIA AREA BOUNDARY
INVERTER BASE
SEWERAGE PIPING
BUILDING PLAN OVERVIEW KHOI-SUN SOLAR FACILITY
KHOI-SUN SOLAR FACILITY SCHUITDRIFT



INFRA-STRUCTURE	
ELECTRICAL LINE	
EXISTING ROUTE	
INTERNAL ACCESS WAYS	
HIGHLY SENSITIVE	
VERY HIGHLY SENSITIVE	
EIA AREA BOUNDARY	

LAYOUT INFRA

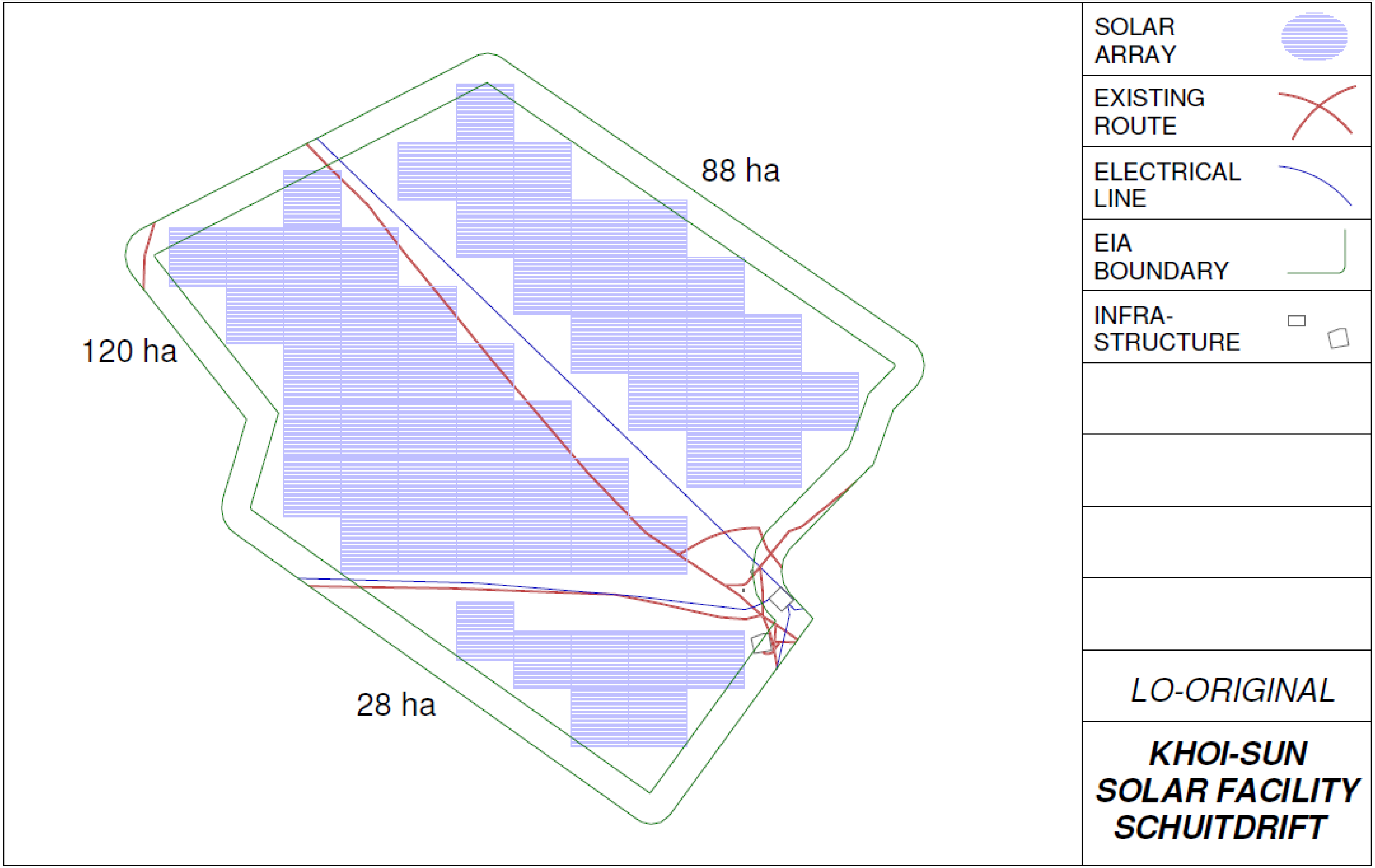
KHOI-SUN SOLAR FACILITY SCHUITDRIFT



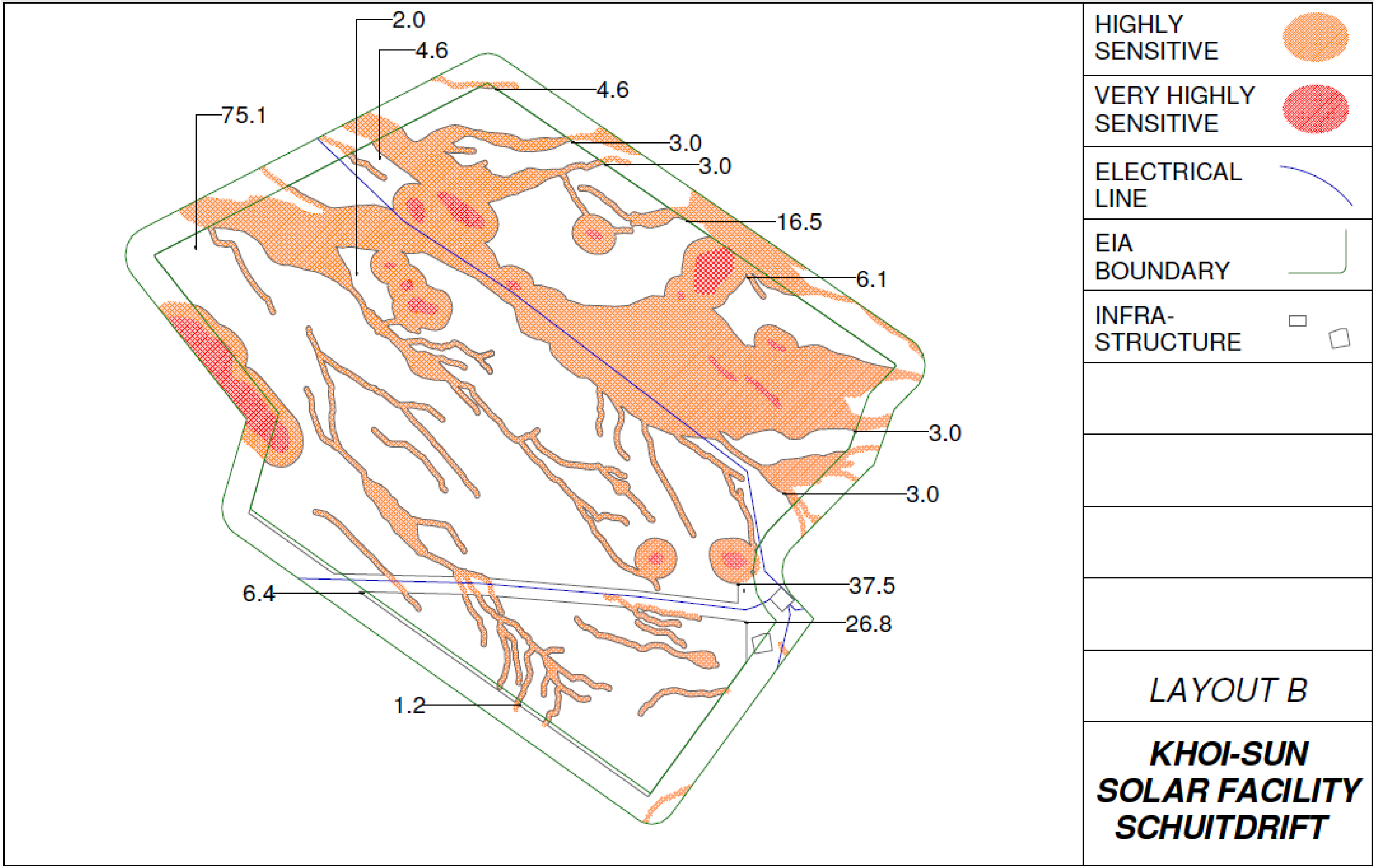
LAYOUT AREA A

KHOI-SUN SOLAR FACILITY SCHUITDRIFT

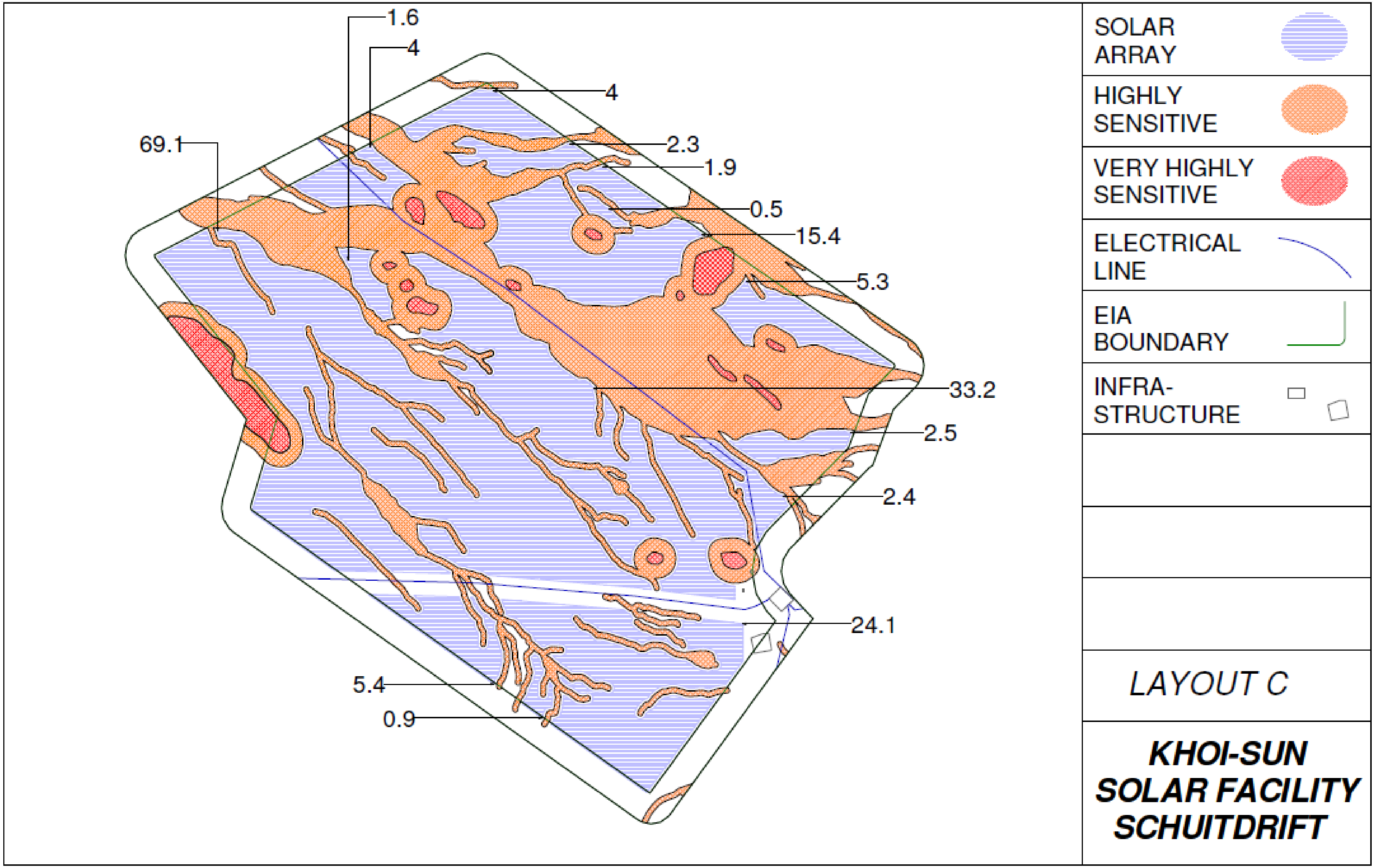
Layout Alternative 1 - Initial Uniform Layout



Layout Alternative 2 - Scattered layout with a 2.5m buffer on all washes



Layout Alternative 3 - Scattered layout with a 5m buffer on all washes



Khoi-Sun Development

October

2012

Facility Layout Report pertaining to the Khoi-Sun Development Solar Project. Compiled by Solek (Renewable Energy Engineers)

Layout Report

Contents

List of Figures

Khoi-Sun Development 75MW Solar Site

The Figure below shows the aerial view of the proposed 75MW Solar Facility. The section indicated in red is a 450 hectare portion of the farm Skuitdrift 426, Kenhardt District in the Northern Cape Province. (Please note that all images refer to North as the top of the page unless otherwise specified)

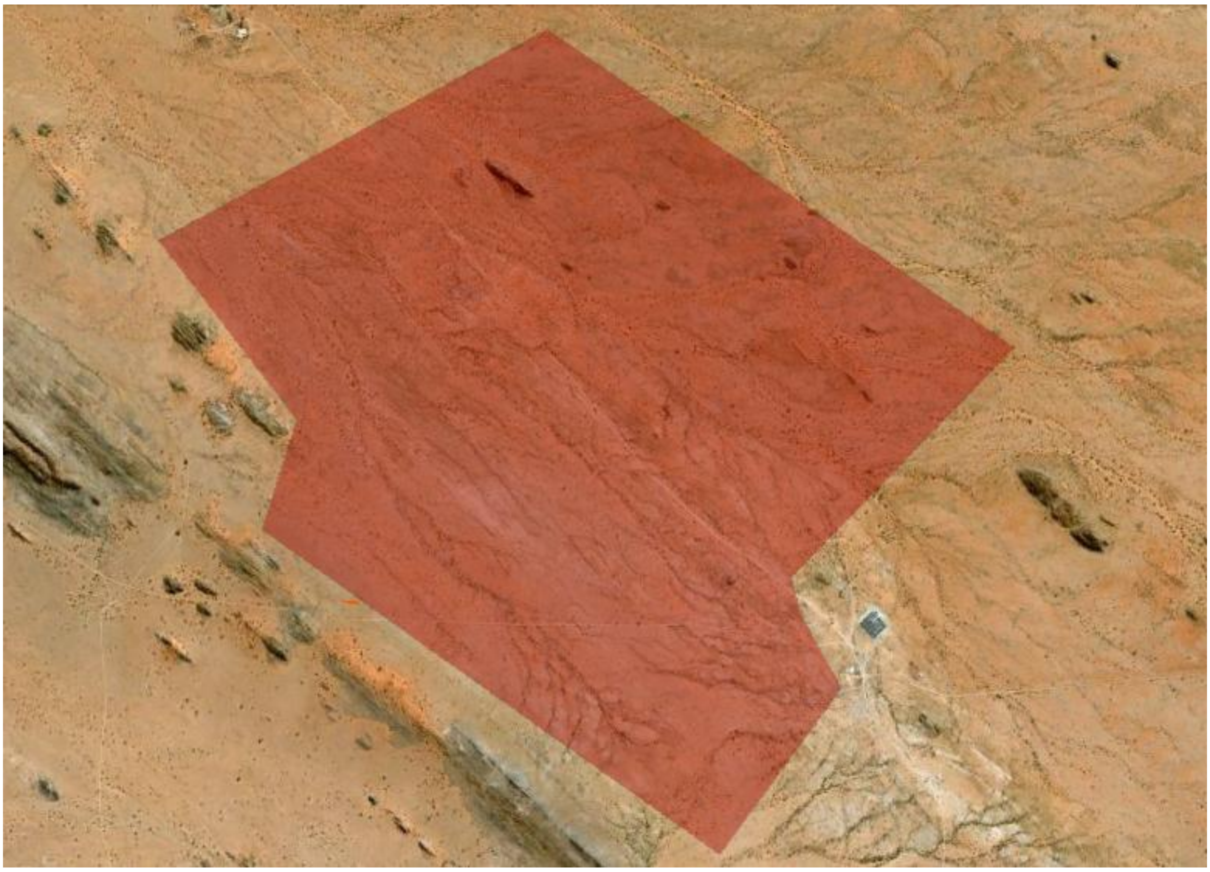


Figure 1: Areal view of proposed site for PV facility and surroundings

The potential 450 hectare area was identified due its level surface, general characteristics of the substrate and the close proximity to the Skuitdrift 132kV to 33kV substation, as indicated in Figure 1 above. The low concentration of nutrients in the soil also means that vegetation is not very dense or high, eliminating the chances of casting shadows on the solar arrays or having an effect of food security.

After further studies into the environmental matters applicable to the Skuitdrift area and alternatives surrounding solar farm construction, it was decided to move the focus to the Southern section of the identified area. The Figure below shows that the focus area was practically halved by only focussing on the superimposed area indicated in blue. It should be noted that the proposed solar arrays would be facing north to yield the best possible performance, influencing the shape of the proposed focus area.

Highlighted in the Figure is the existing infrastructure that crosses the potential site of which the most important is the 132kV high tension transmission line and two roads used in servicing the surrounding area.

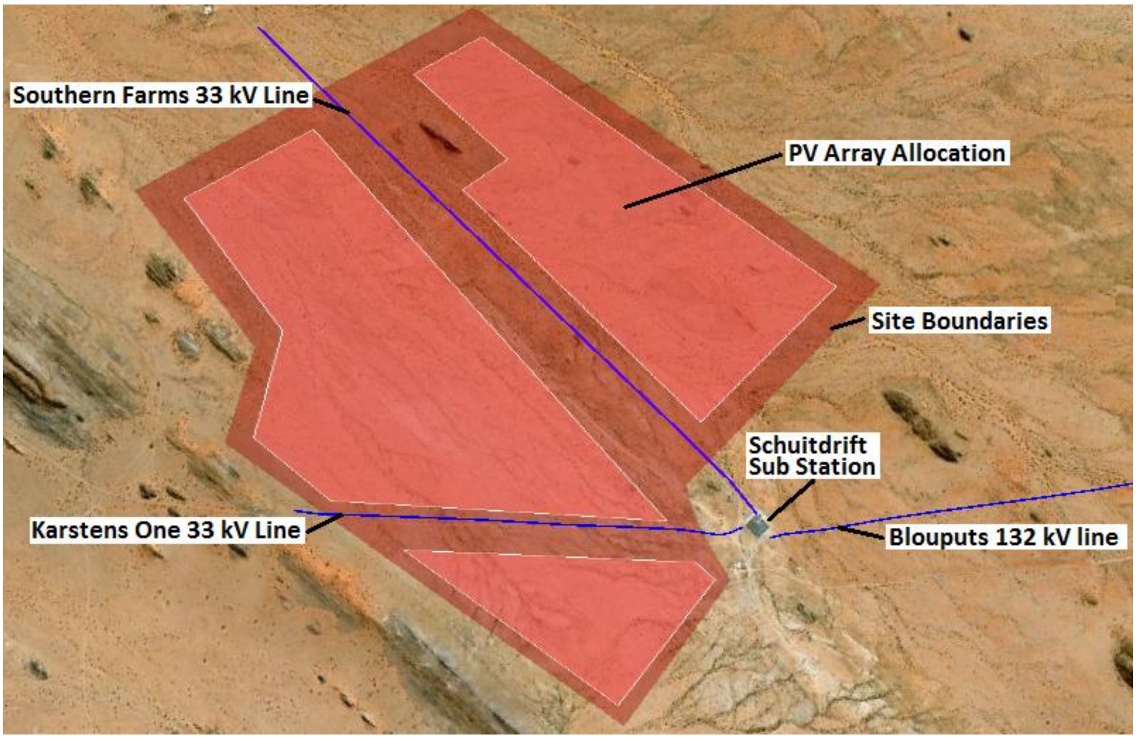


Figure 2: Focus areas for the final 75 MW Solar Site

Preferred Layout

The following Figure is the layout proposed for the 75MW Solar Farm within the 450 hectare accessed area. The infrastructure of the solar facility is to be 250 hectare and is aimed at having the lowest possible environmental impact while still keeping the project economically viable.

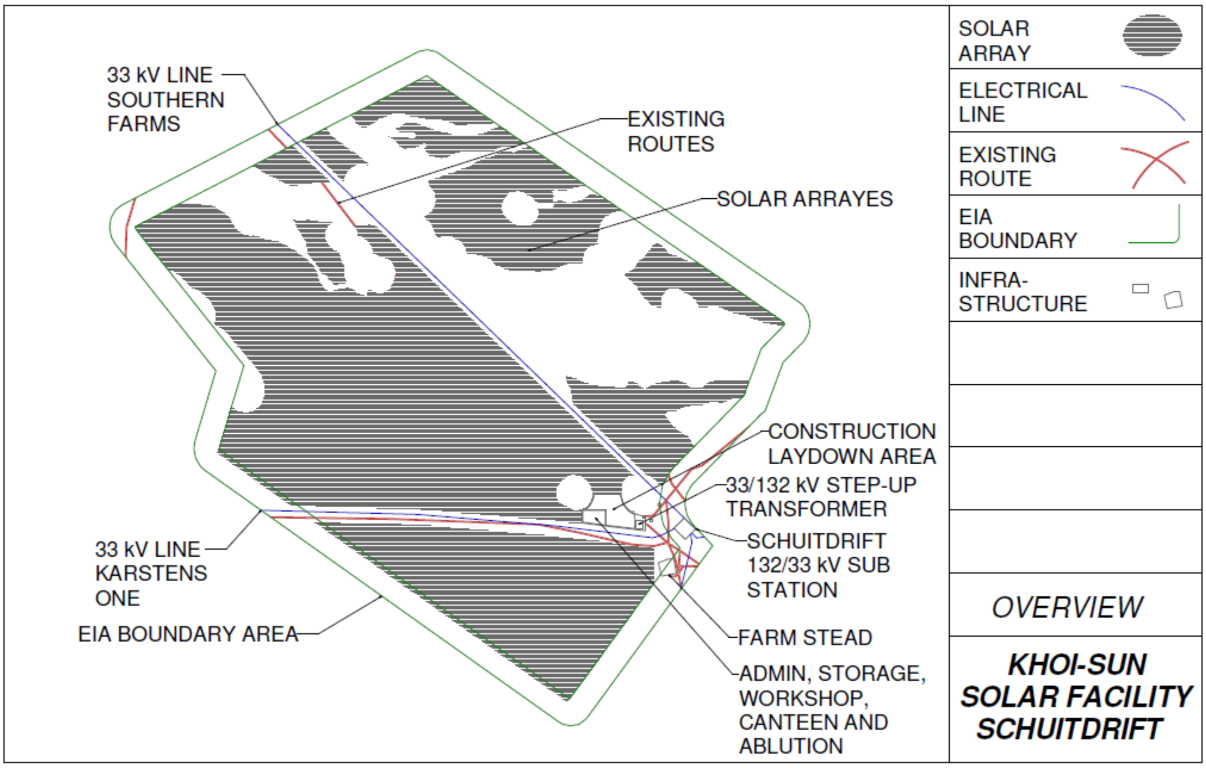


Figure 3: Preferred layout of Solar Arrays

The solar arrays are put together with strings of solar modules connected in series and mounted onto single axis tracking systems. These frames are installed with the single tracking axis in an east-west direction to maximise the systems output. Each of the arrays is controlled individually and standardised systems are preferred for economic and practical reasons. The standardised length would be between 50 and 200m long. The single axis tracking system poses an enormous advantage over a fixed frame in that the tracking system would yield the maximum possible power for a period of time during every day of all seasons.

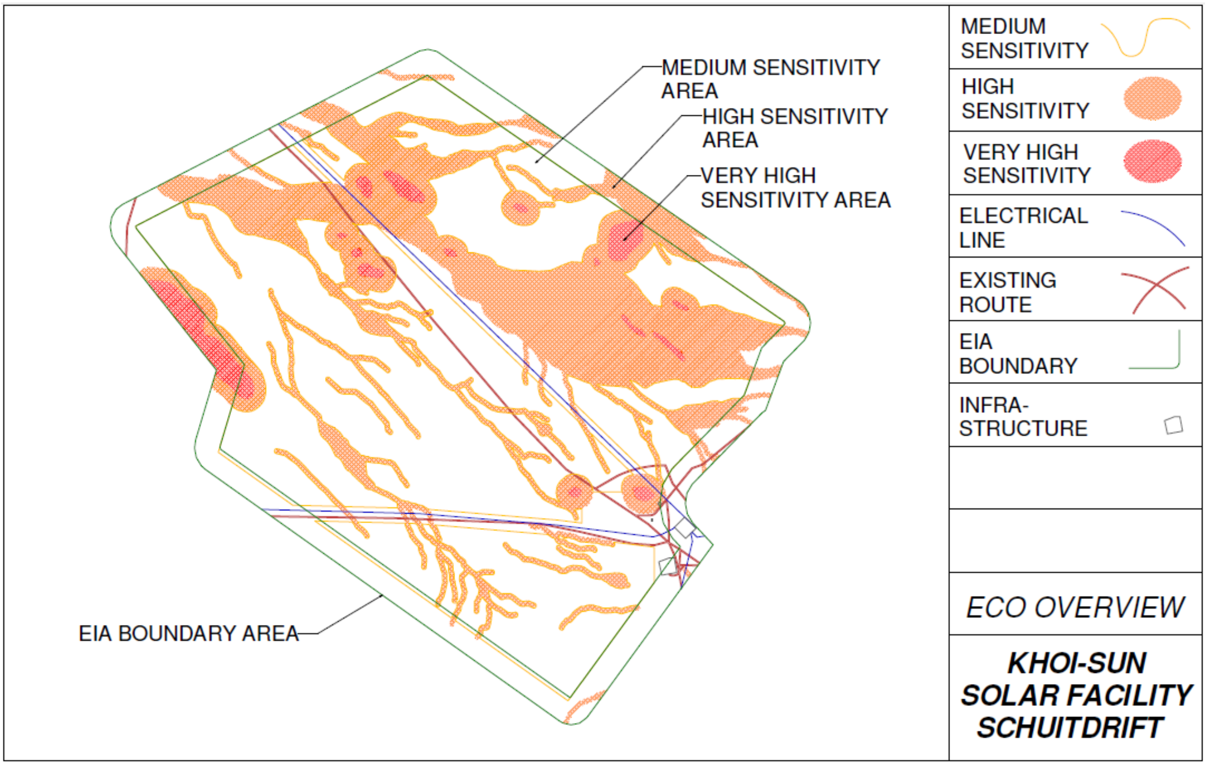


Figure 4: Ecological map of the specified area

As indicated in the following two figures the solar arrays will be placed in such a way that it would have the least influence on the washes while keeping clear of the servitudes around the 33kV Eskom lines as well as avoiding the ecological sensitive areas where practically possible. The eastern side of the investigated area has a much larger concentration of washes which can easily be seen from the initial aerial view and the previous figures. These washes are also slightly deeper which indicates that if water were to flow through the area, the highest concentration would be in this area. Although the annual rainfall within this region is extremely low the drainage lines were carefully considered and the most viable alternative selected.

Because of the relatively dry climate and low rainfall natural vegetation tend to be more dense in the drainage washes, thus the layout which has the smallest impact on the washes would also have the smallest impact on the vegetation. Once again the eastern might be boundary habitat to the bulk of the vegetation which could include *Acacia Erioloba*. The layout is aimed at preserving this tree species but in the case where *Acacia Erioloba* is present, the trees would be relocated or replaced to a more suitable area within the area boundary.

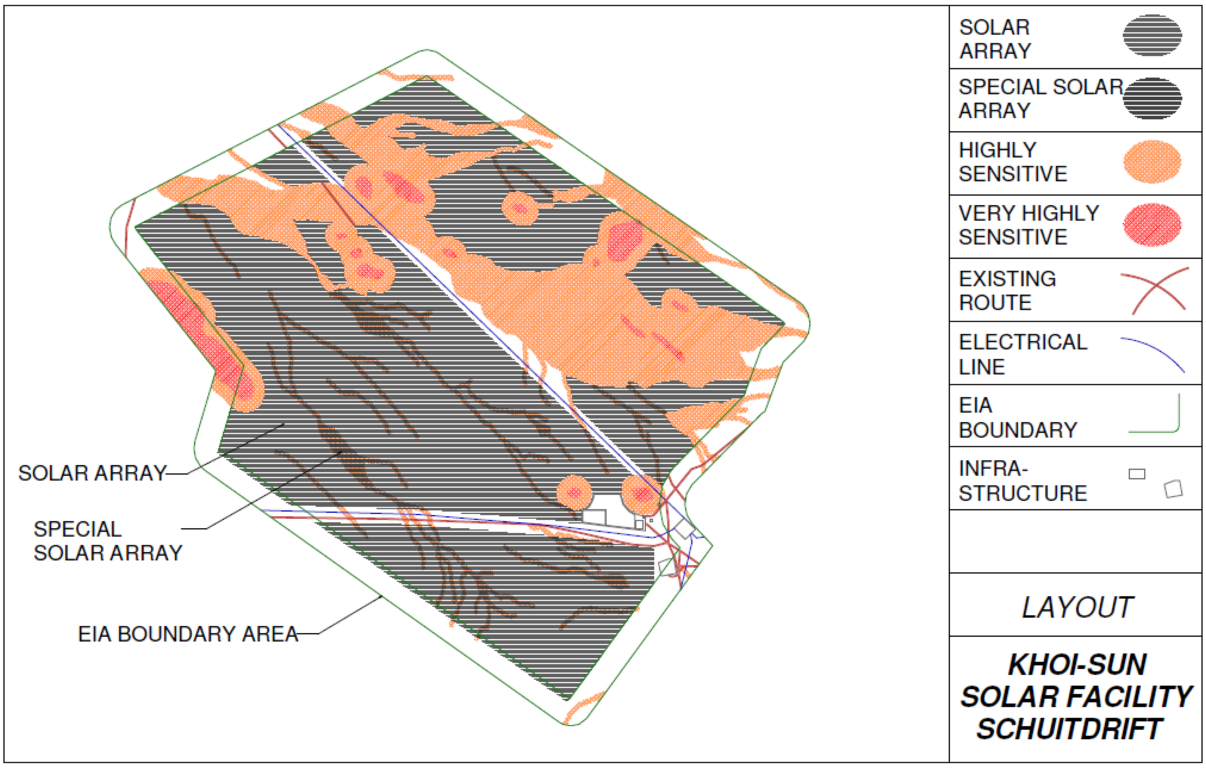


Figure 5: Preferred layout with sensitive areas indicated

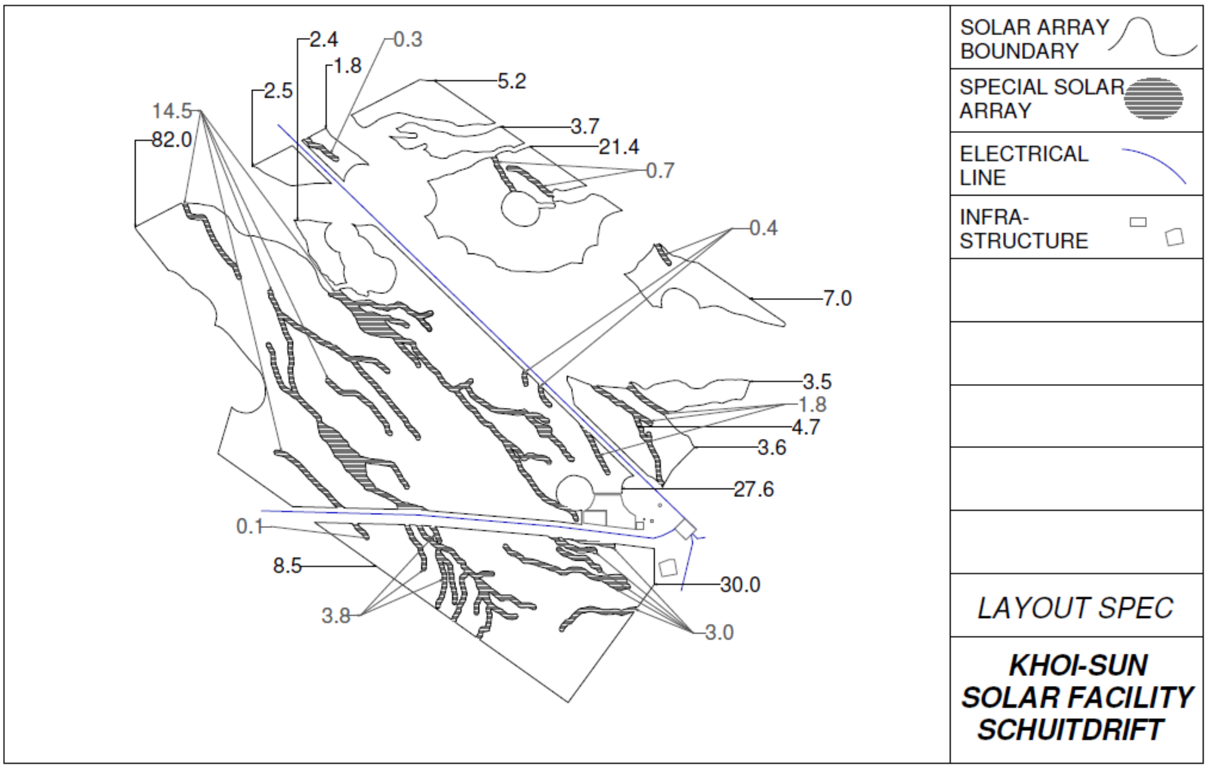


Figure 6: Preferred layout with sensitive areas and the relevant area sizes indicated

The boundary of the investigated area was selected by staying clear of the highly sensitive and very highly sensitive areas. These sensitive areas are not suitable for solar installations at all due to the change in elevation (causing shadows) and the nature of its highly sensitive biological habitat.

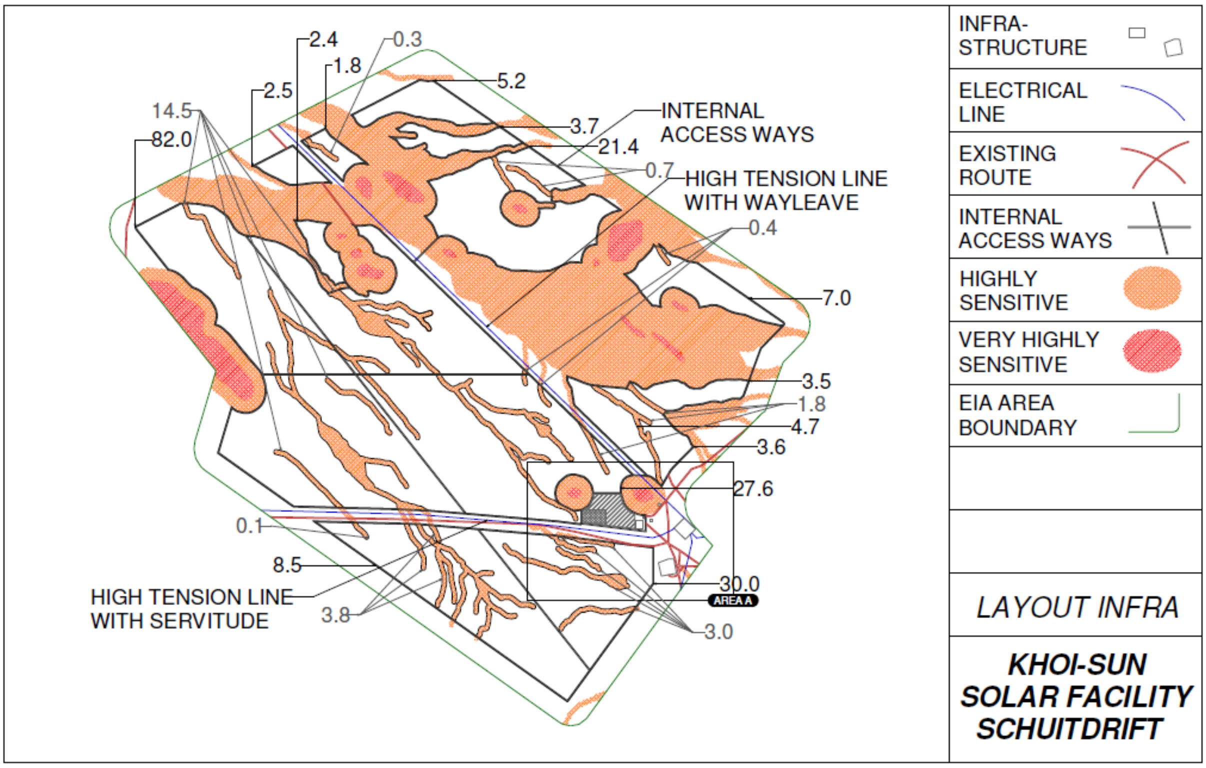


Figure 7: Preferred layout with emphasis on the most probable infrastructure layout

The preliminary electrical design was done using modular layouts of 1 megawatt each. Thus each solar panel string capable of generating 1 megawatt of electricity would be connected to an inverter before being connected to the transformer (Transmitting 75MW) shown in Figure 8.

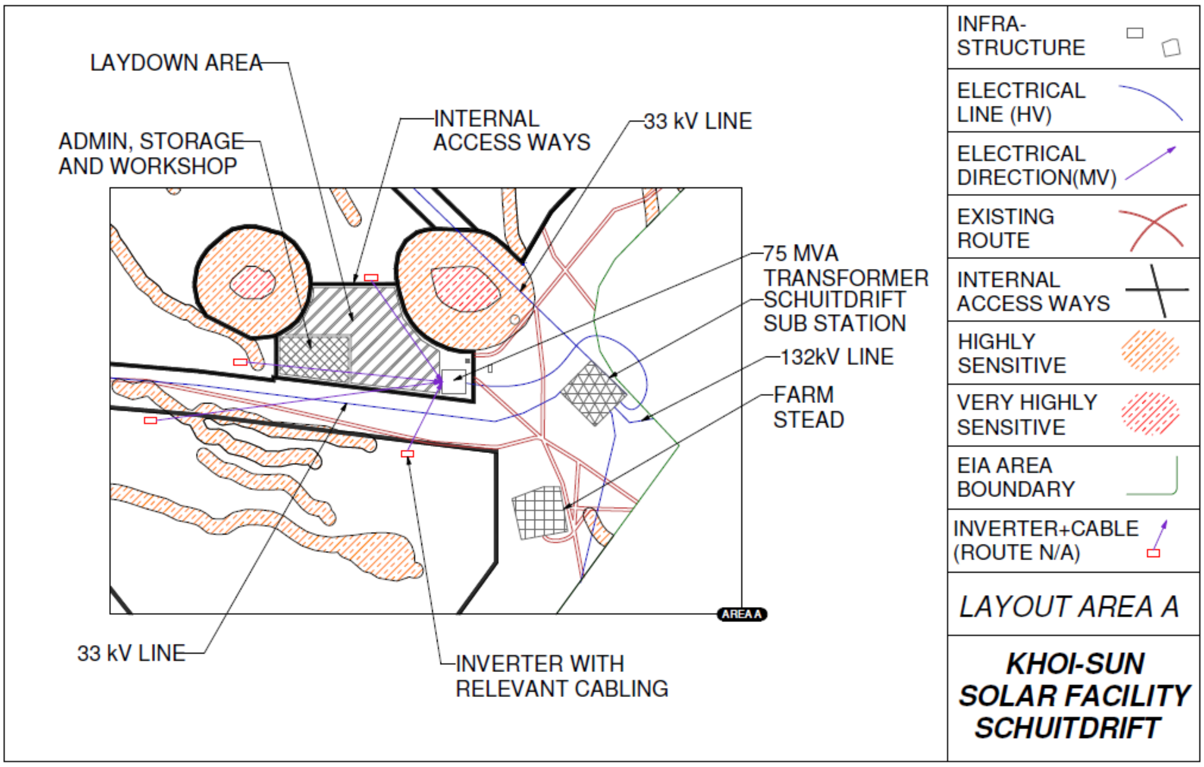


Figure 8: Preferred layout with most probable layout of Focus Area A

Figure 8 also shows the Laydown area which would be used during the construction phase of the project to lay down all equipment and construction materials. The area indicated is ideally located for material storage and to do product assemblies before it is moved to the allocated area for installation. The laydown is also close to both the administration building and security checkpoint.

The solar frames will be installed using a ramming method which would have the minimum impact on the environment. The ramming poles would be driven in as far as practically possible from all washes and according to the ecological constraints. This eliminates the need for the use of cement or polymeric products which could have a significant long term effect on the biology of the surrounding area. This method also allows the frames to have a very small mounting footprint which would avoid any obstructions to natural water flow. During the operation of the proposed plant the area would be patrolled regularly and any potential blockage could be removed swiftly as a precautionary measure avoiding the risk of erosion. Personnel would also be trained to identify early signs of erosion and how to mitigate the potential risks.

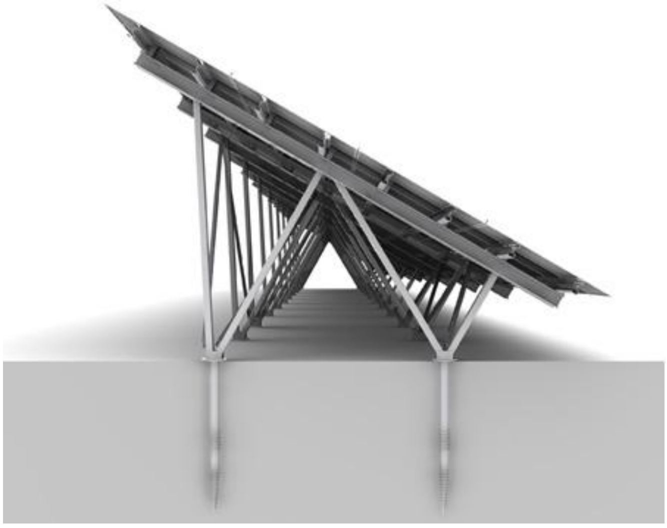


Figure 9: Rammed or screwed mounting method on fixed frame (image www.expo21xx.com)

The physical process of ramming the anchors into the ground is done using yellow equipment (typically on tracks). In the case where earth screws or rock anchors would be more suitable the rammed pole would be replaced by one of the former. The effect on the environment would be similar for any of the selected processes. The Figure below shows that equipment being used in the ramming process. Some of the ground covering in the medium sensitivity area will be cleared to do the frame installation accurately. Although the site is very flat, some minor excavation may be necessary in certain medium sensitivity areas.

In the areas of high sensitivity vegetation would be left in place to avoid the risk of erosion. In the unlikely case where brush or trees are high enough to cast shadows it would be trimmed to size. As far as practically possible these borders will be kept undisturbed.

Figure 10: Construction and Equipment (Image from www.aceinfra.com and www.kaska.eu)

The electrical feeding line would leave the proposed area towards the East. This electrical line would run along the existing infrastructure to minimise the effect on the environment. This electrical line would be kept above ground and would feed into the 132kV side of the substation located to the Eastern side of the substation.

A 75MW installation would most probably make use of 75 inverting stations for converting the power produced to such a form that it could be fed into the electricity grid through the Skuitdrift substation. These inverting stations are connected to a series of arrays and would be placed along the service roads to give quick and easy access. The final placement of the inverting stations would take the ground conditions into considerations, meaning that suitable areas having a minimal impact on the environment would be preferred. Interconnecting cables may be trenched where practically possible but in areas of high sensitivity cables would be mounted to the structure avoiding excessive excavation works and clearing of vegetation. These inverter stations would typically be built into a purpose build container measuring 10 x 2.5m, having a footprint of 25 square meters.

The preferred inverting stations would not make use of excessive air condition cooling and would house a dry solid transformer. This reduces the threat of environmental risks associated with oil cooled transformers. By using advanced cooling methods air condition noise could also be limited.

The main storage, workshop, ablution and admin facilities are indicated to the south to avoid shadows being cast onto the solar arrays. The final storage and admin areas would also be selected to minimise its impact on the environment by considering the ground conditions and the ecology of the surrounding areas. Since this area may host more human activity than most other parts of the solar facility, it is important to take the surrounding habitat into consideration. The structure erected would be around 2000 square meters in area and is referred to in the preceding drawings as the Storage and Admin facility. Water to the facilities will be supplied by ten 10kl water tanks. These tanks will also be used as redundant water for operation of the plant.

In the case where access roads cross the washes or are in the close vicinity of the washes special care and precautionary measures must be taken to mitigate the risk of erosion due to ground disturbances. By incorporating precast concrete infrastructure into the construction of these roads the risk of the roads acting as water channels could be avoided. Special attention to drainage, water flow and erosion will be given and potential risks mitigated by applying appropriate building methods.

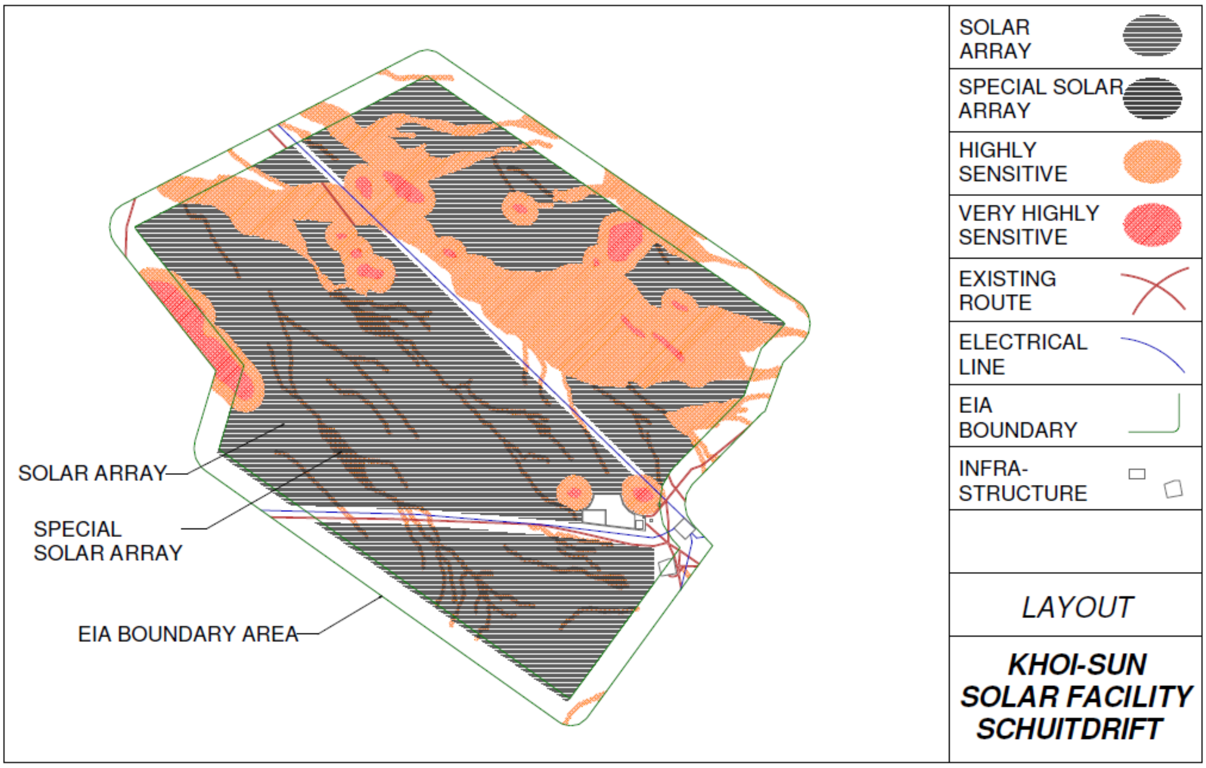


Figure 11: Preferred layout (overview repeat)

Alternatives Considered

Layout Alternatives

During the planning phase of the project numerous layouts and technologies were taken into consideration before the preferred proposal was decided upon. Three of the major points which lead to the preferred proposal are:

- Minimal disturbance to water washes and highly sensitive areas
- Minimum distance to the substation
- Area of around 250 ha to ensure the project would be economically viable

The factor having the single biggest influence on point number one is the mounting technology. The preferred technology allows arrays to be constructed over the wash lines and high sensitivity areas while having a minimal effect on the vegetation mitigating the chances of erosion. The following layout was done to show the possible layout by moving the 33kV electrical line feeding Southern Farms and the second without consulting the ecological map (during preliminary design stages) by keeping the area as uniform as possible. The final two layouts following on that kept a 2.5m and 5m buffer around all the washes.

Shifting the Southern Farms 33kV line towards the north east

The following figures show the layout possibilities when moving the 33kV Southern Farms line towards the North East. The area influenced is also compared to the preferred layout in the table below.

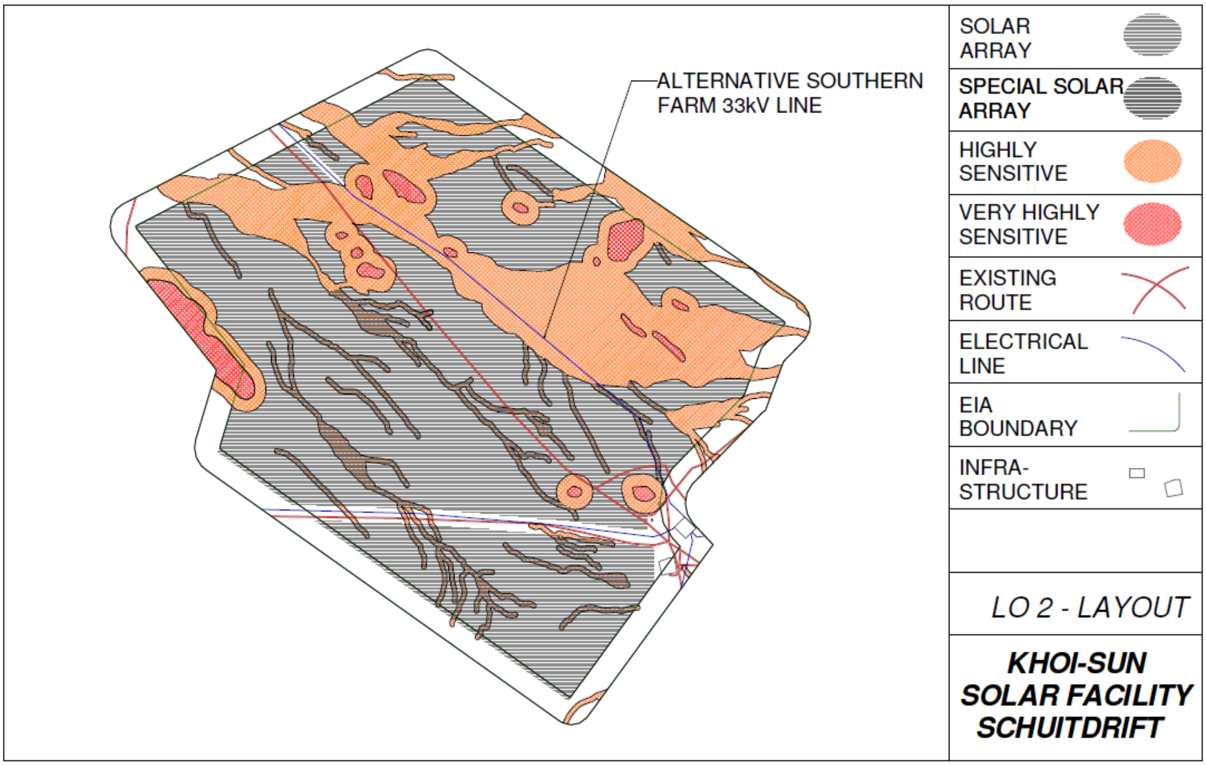


Figure 12: Layout 2 overview

One should consider the advantages of shifting the line with the cost and administration going along with such a line shift and the solar array area gain.

Table 1 Covered area (approximates)

Area covered when line is moved (Layout 2)		**Area covered with existing line (Preferred Layout)**	
Solar Array Area	Sensitive Area covered	**Solar Array Area**	Sensitive Area covered
123.2	0.3	**82**	14.5
2.6	0.7	**2.5**	0.3
2.4	0.2	**2.4**	0.7
1.9	1.6	**1.8**	0.4
5.2	0.4	**5.2**	1.8
21.4	1.1	**3.7**	3
7	1	**21.4**	3.8
3.5	1.3	**7**	0.1
3.6	0.7	**3.5**	
30	3.3	**4.7**	
8.5	0.5	**3.6**	
	0.1	**27.6**	
	0.6	**30**	
	6	**8.5**	
	0.7		
	0.7		
	6.5		
209.3	**25.7**	**203.9**	**24.6**

During the possible shift the Southern Farm community would be left without electricity and water (Southern Farms is dependent on pumped water from the Orange River). This is something to take into consideration, seeing that this holds major risks and any delay could cause huge problems holding great penalties.

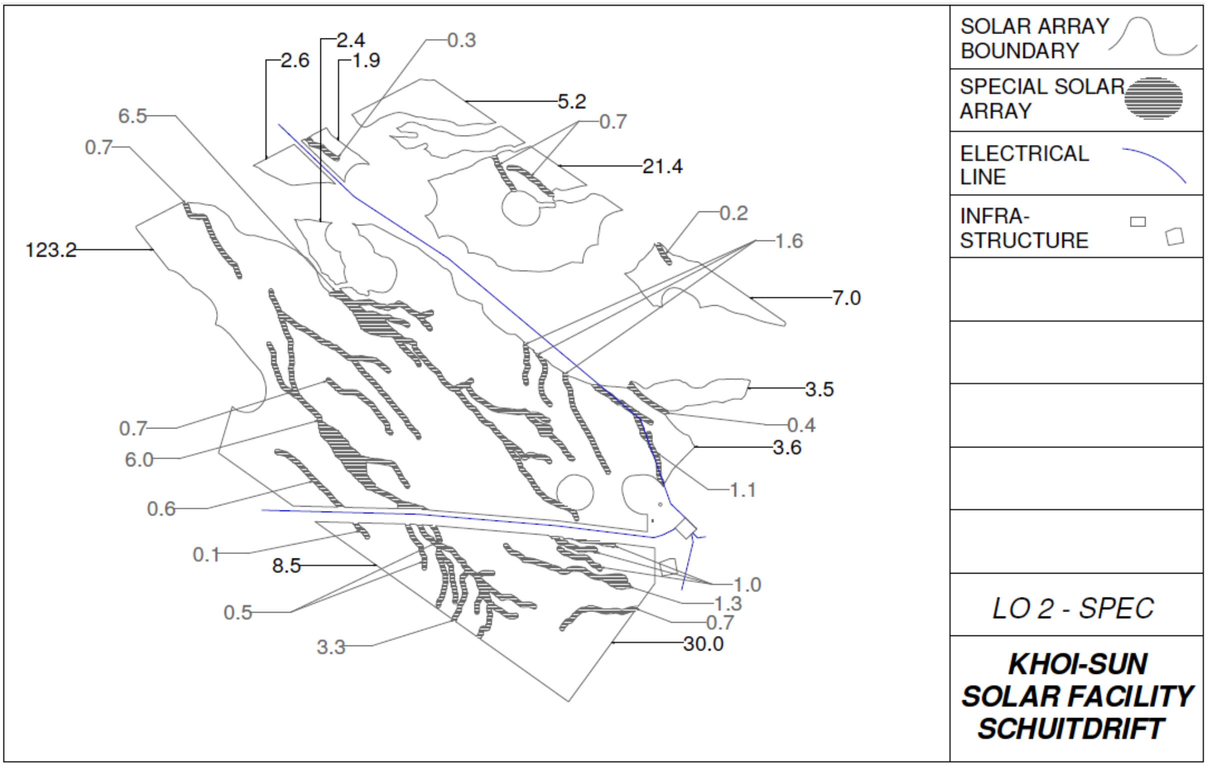


Figure 13: Layout 2 specification

Preliminary Layouts:

1. Original uniform layout

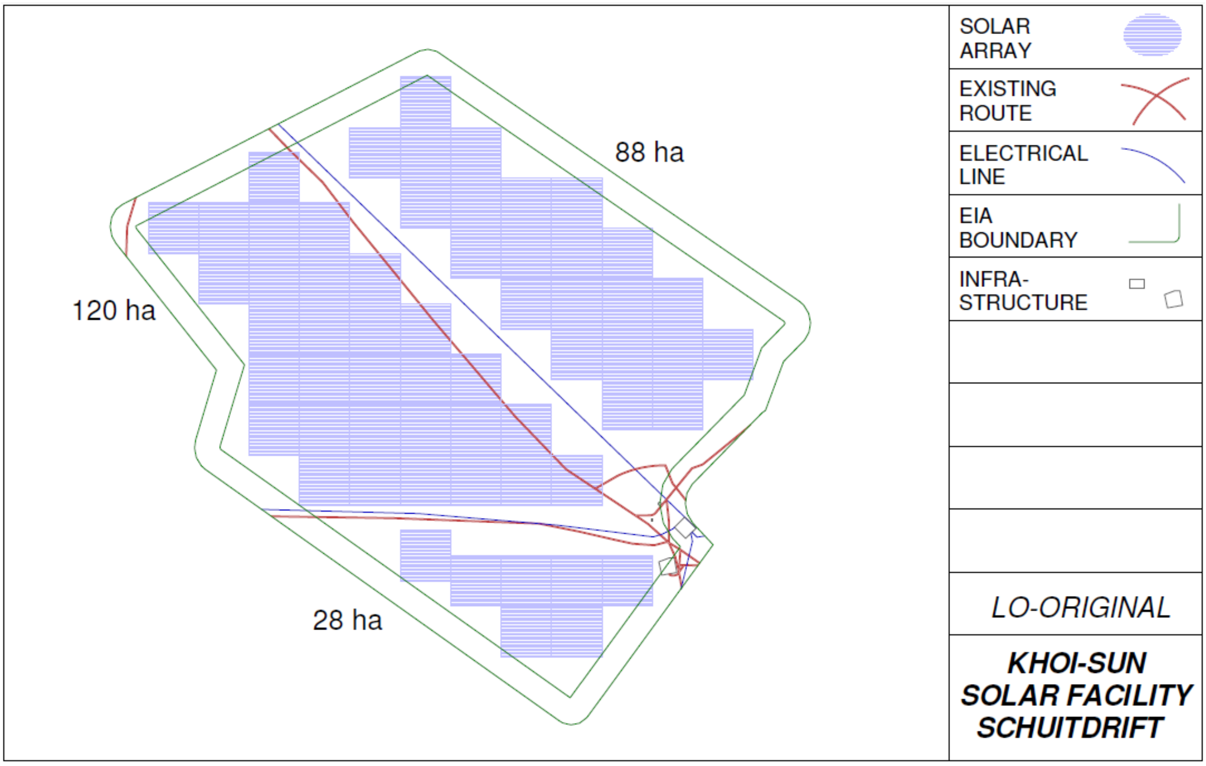


Figure 14: Original uniform layout

2. Scattered layout with 2.5m wash boundary

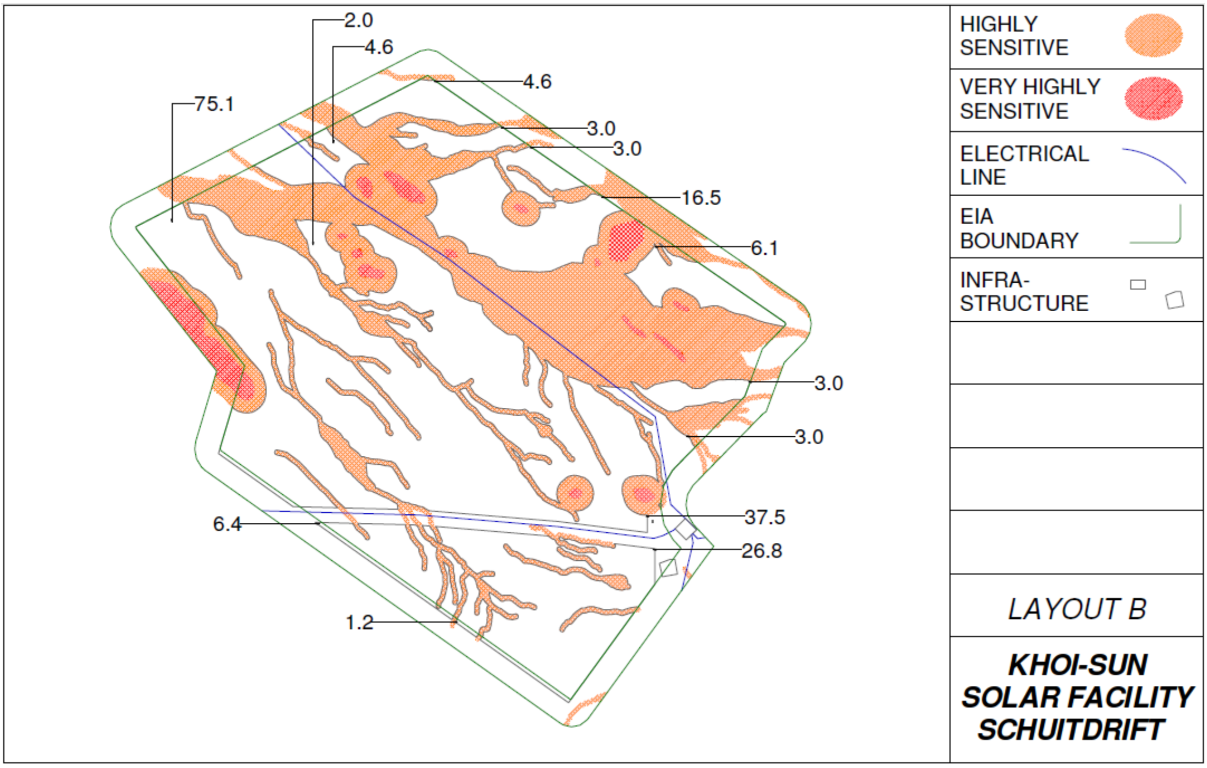


Figure 15: Layout keeping a 2.5m buffer from any indicated wash, area sizes indicated

When the layout is scattered towards the west the development would have a slightly smaller impact on the high sensitive areas. This increases the risk of erosion and would require more expensive building techniques and equipment.

By scattering the solar arrays the modular or bulk engineering principles are essentially lost. By this is meant that may custom solutions would be required to avoid all buffers significantly increasing the price and reducing the amount of panels that would fit into the 250 hectare area. This would reduce the peak power rating of the plant to fall below the 75MW mark. Further it should be noted that all the boundaries around the highly sensitive areas will be physically marked by an ecologist before any construction is started.

3. Scattered layout with 5m wash boundary

By moving the layout toward the east, a significant part of the wash is avoided. Although the bulk effect is slightly recovered and less customisation is required, the probability of reaching the 75MW peak power within 250ha is significantly reduced. Thus the power produced per square area of land is reduced, lowering the plant efficiency damping financial gain.

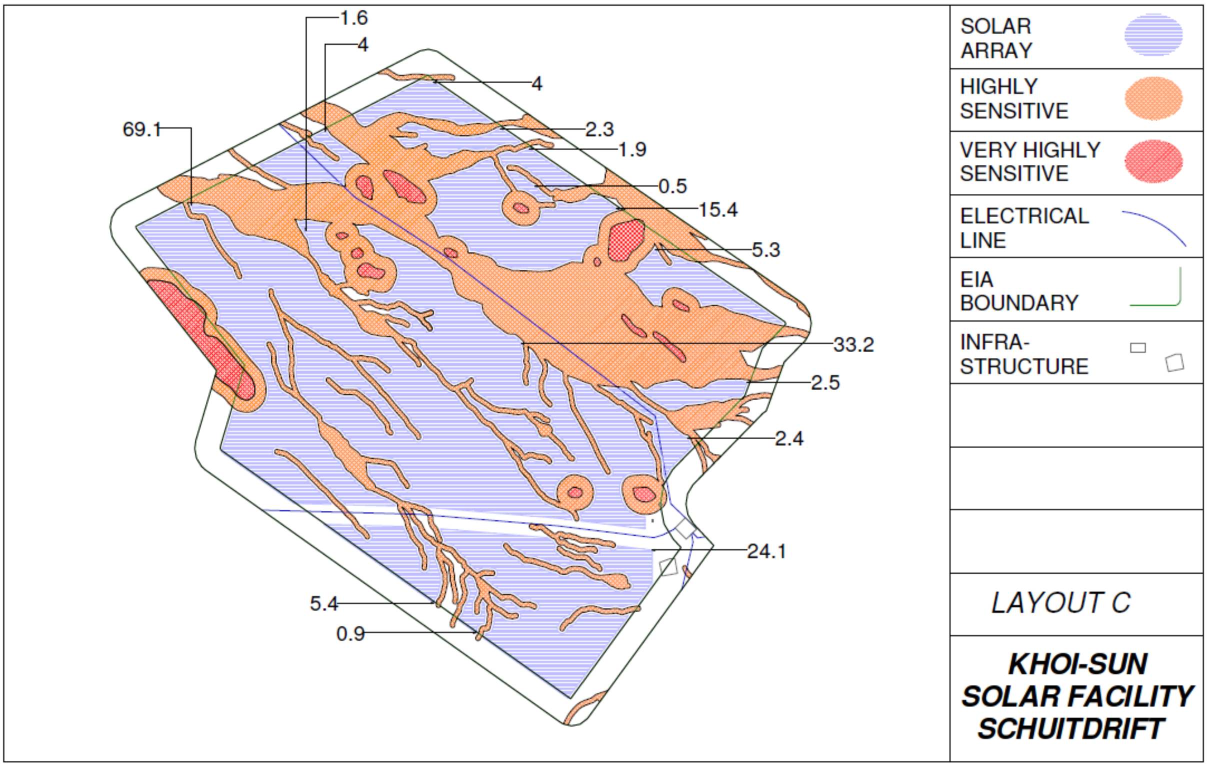


Figure 16: Layout keeping a 5m buffer from any indicated wash, with sizes indicated

Alternative Solar Technology

Double Axis tracking

Two axis tracking systems were investigated due to the high yield and efficient operation of the technology. Systems incorporating this technology are very effective due to sun being tracked in more than once axis. This allows maximum radiation over the whole solar module.

Figure 17: Double axis tracking system (image from www.treehugger.com)

From the Figure above one could easily see that a much larger ground area is required due to the elevated angle combined with the rotational axis, casting very long shadows. The wind loading on this type of structure plays a much larger role when compared to the single axis technology preferred. The foundation required by this system requires steel reinforcing and a significant amount of concrete to resist the expected wind loading.

Due to the complexity of the control system required to operate a system like this, it is not adequately suited to isolated areas where spare parts are few and far between. Therefore more spares must be kept to keep the plant in a running condition and increasing capital layout costs.

A single axis tracking system yields maximum available power for a certain period of everyday throughout the year while stationary system would only yield the maximum available power for a certain period of time in a single season. Although the double axis technology increases this highly efficient time of the day the capital input is difficult to justify unless vast areas of land is available at a very low cost.

Thin Film Solar Modules

Opposing the thick film or multi crystalline solar modules which forms part of the preferred proposal is thin film technology (amorphous silicon or cadmium telluride). This technology is not suited to the conditions of the Northern Cape Province due to its inferior performance at high temperatures. With ambient temperatures regularly exceeding 40 °C, the proposed thick film technology easily outperforms the alternative to such an extent that any financial benefit can be disregarded.

Anchoring Alternatives

Cast Foundations

The most common foundation used for anchoring single axis tracking solar frames is concrete cast foundations. This type of foundation requires a foundation trench which is filled with concrete and reinforcing steel. Once the concrete has cured the frame could either be welded or bolted to protruding reinforcing steel, or the frame could be left to cure within the concrete.

This technology is much more suitable to European conditions and not for the extremely hard surfaces of the proposed site unless the concrete is casted on the surface using shutters. This process poses the risk of concrete spillages which could have long term negative effects. Further drawbacks applicable the proposed site is the negative influence on water flow, increasing the risk of erosion.

Figure 18: Shuttered foundation with double axis tracking (image www.tradekorea.com)

Precast Footing

One of the alternatives considered for the mounting of the frames is pre-cast concrete footing. This is based on the same principle as the on surface foundation casted using removable shutters. The pre-cast concrete feet could be manufactured off site, reducing the risk of concrete spillages and the need for exorbitant amounts of water during the construction phase of the project.

The main drawback associated with pre-cast footing is the large physical footprint required to keep the structures stable. Further it may also be required that these footings be bolted or grouted to the ground surface for stability. This large footprint also increases the risk of having a negative effect on water flow increasing the risk for erosion.

Figure 19: Precast footing on tilted single axis tracker (image www.ens-newswire.com)