

Infill Assessment using Simulated Migration Amplitude - A Case Study from Eastern Offshore India

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Keywords

Infill, SMA, Coverage, Feather, Fresnel Zone

Summary

Coverage gaps are very common in marine 3D seismic data acquisition. The size of coverage holes is small at near offsets and gradually increases at middle and far offsets due to streamer feathering. To recover the lost data in these coverage holes, infill has to be planned. Improper infill planning escalates the project cost, turnaround time and HSE exposures at sea. Optimization of infill based on geophysical criteria is crucial without compromising on data quality.

The objective of this study is to assess infill requirement quantitatively by determining the relaxation criteria of coverage holes. This study is carried out at nears, near-mids, far-mids and far offset groups based on amplitude variations using Simulated Migration Amplitude (SMA). It considers both the shallowest and deepest target levels.

Introduction

The subsurface imaging can be enhanced when imaginary cells of surface, termed as bin, has a collection of data points which is quantified by foldage. For any 3D seismic acquisition project, coverage specifications are crucial which dictates an optimal amount of data coverage to be acquired across the entire survey area.

During marine 3D seismic data acquisition, uniform coverage is usually not achieved in a single vessel pass. This loss or overlap of coverage is common in marine 3D data acquisition is due to streamer feathering. Feathering is caused by many factors like oceanic currents, weather window, survey location etc. There is minimal control of streamers at far-mids and fars compared to nears and near-mids and this results in more coverage gaps at farther end of streamer. In order to account for these data coverage deficits, additional seismic lines – infill lines are required which are termed as infill shooting. An effective infill

decision is highly required to acquire an appropriate quantity of infill without deteriorating the quality.

This paper describes an effective and efficient pre-survey geophysical approach for infill planning through modelling exercise. The entire work evidently illustrates that the modelling predictions are conservative and hence can be used as an effective infill management tool.

Methodology

NORSAR-3D modelling package contains Simulated Migration Amplitude (SMA), a technique to model illumination amplitudes that correspond to those appearing in depth migrated seismic data. By taking advantage of the ray generated local travel time field in the vicinity of each reflection point, it is possible to simulate the migration process locally, giving more realistic amplitudes where both the seismic pulse and the Fresnel effect are included.

The sub-surface illumination can be depicted in simulated Pre-stack depth migration (PSDM) amplitudes. It gives a preview of the seismic data quality which can be expected from the real data acquisition as this method estimates final reflection amplitudes during acquisition. It then becomes possible to evaluate the data quality more realistically and reliably, whether infill shooting is required or not. Hence, acquisition will be more cost effective without compromising the data quality.

A 3D model (Figure 1) was prepared for survey area with given interpreted 3D depth horizons and velocity property. These horizons were edited and smoothed to meet ray-tracing requirements. Synthetic model was populated with velocity and density properties. Densities were calculated with Gardeners equation using P velocities. S-velocities. were derived from P velocities using a V_p/V_s ratio of 1.7321.

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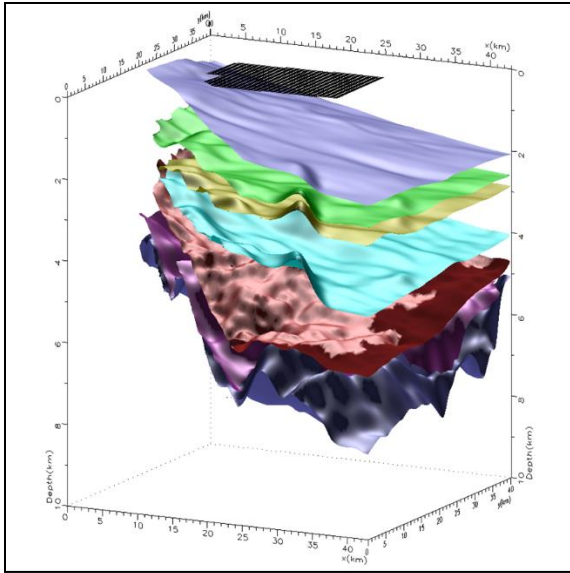


Figure 1: 3D synthetic model of survey area

The streamer geometry of 8 x 100 x 8000 m and parallel shooting with dual source (Flip-flop) at 25 m shot interval is used. The coverage gaps were created at locations selected based on targets maximum dips, depths and geological complexities such as facies

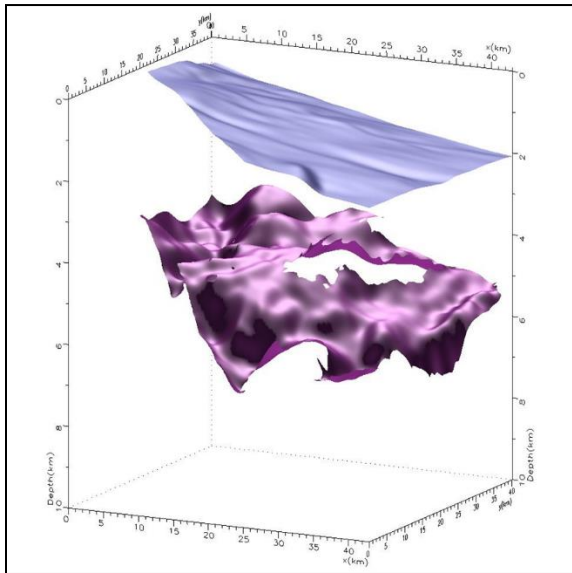


Figure 2: Shallow and deep targets of 3D Model

representation and continuity, structural integrity and faults.

Coverage holes of different widths (starting from 100 m to 500 m with an increment of 100 m) each of 12.5 km in length were generated along a subline depending on Fresnel Zone. Shallow and deep targets (Figure 2) were selected to assess the impact of coverage hole with reference to the ideal dataset (coverage with no hole). For both targets, holes were created on the basis of calculated zero offset Fresnel zones to evaluate the SMA results.

To calculate Fresnel zone, velocity of 2000 m/s and 3130 m/s and the dominant frequency of 30 Hz and 15 Hz was used for shallow and deep targets respectively.

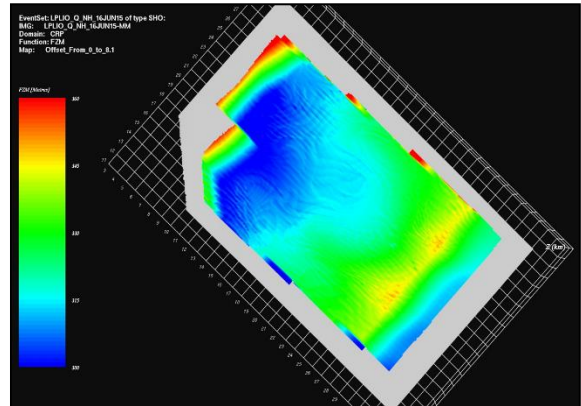


Figure 3: Fresnel Zone map of shallow target

The formula for the zero-offset Fresnel zone,

$$R_f = \frac{v}{2} \sqrt{\frac{t}{f}}$$

Where, v Velocity
t Two way time to the reflector
f Dominant frequency

The TWTs, the frequencies and the velocities that are used to find the zero-offset Fresnel zone will differ for different survey areas.

The Zero offset Fresnel zone for the two targets were 320 m and 857 m respectively. This Fresnel zone

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would increase from shallow to deep and zero to non-zero offset.

Surveys were created for different coverage hole sizes and ray-tracing is performed for each. The SMA

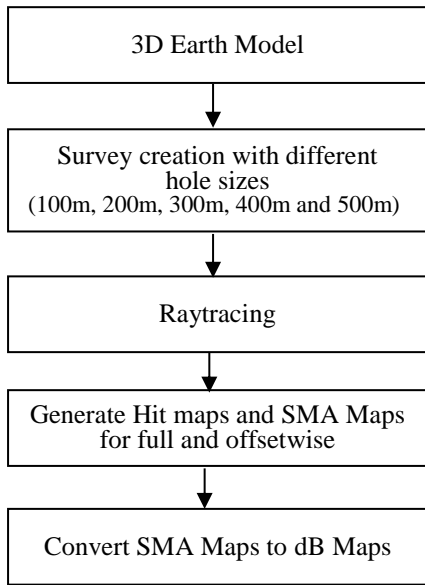


Figure 4: Workflow for SMA Modeling

attribute maps for full, near, near-mids, far-mids and far offsets were generated for different hole sizes ranging from 100 m to 500 m and 100 m to 700 m with an increment of 100 for shallow and deep targets respectively.

SMA maps were further converted to dB maps to quantify the results for better comparison of coverage gaps dataset with reference dataset at various offset groups. The geophysical criteria used for this study with amplitude thresholds of 1 dB as strict and 2 dB as relaxed. (Day and Rekdal, SEG 2005).

Results

For shallow target, Figure 5 shows hit maps with no coverage hole and for hole size of 100 m, 200 m, 300 m, 400 m and 500 m. The taper-on and taper-off are visible as a low hit count in blue which reveals the shooting direction. The red colour corresponds to the number of hits equal or superior to the nominal

coverage for the given streamer length. The impact of coverage hole on hit maps is evident and its crossline width increases with gradual increase in hole-width from 100 m to 500 m.

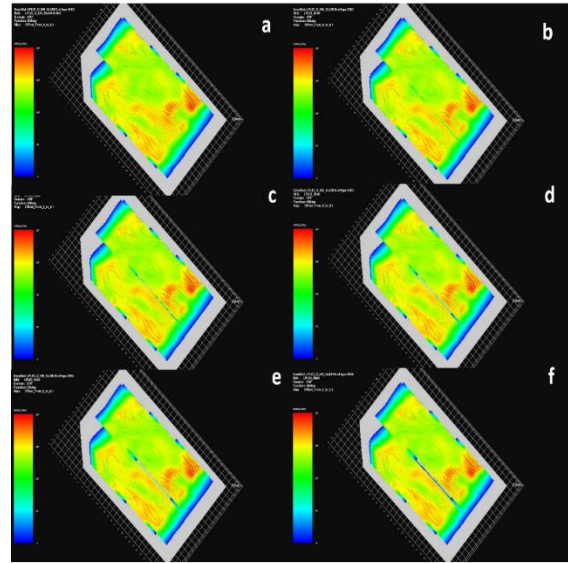


Figure 5: Offset-ALLS; HIT Maps; (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

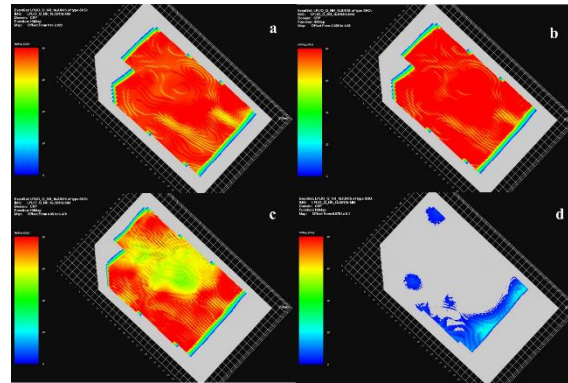


Figure 6: HIT Maps; (a) Nears, (b) Near-Mids, (c) Far-Mids and (d) Fars

Figure 6 shows the hit map for shallow target at nears, near-mids, far-mids and far offset groups for zero coverage hole, which is considered as reference dataset.

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At Far offset group (Figure 6d), it shows that there are no or minimal hits and it is due to post critical reflections. Similarly, offsetwise hit maps were generated for hole widths 100 to 500 m. From these hit maps, it is evident that for coverage hole of sizes 100 m and 200 m, there is minimal reduction in hit percentage but beyond 200 m coverage hole, this loss of hits is gradually increasing from 200 m to 500 m.

Results were analyzed based on SMA maps in dB scale for both the targets at four offset groups, to evaluate the coverage relaxation criteria geophysically. Figure 7 shows the SMA map for dataset with no hole for full offsets. To quantify the results, these SMA maps were further converted to dB maps to correlate them based on geophysical criteria. This helps in understanding the relaxation of coverage hole at a given offset group during seismic data acquisition. Figure 8 and 9 shows the dB maps for full offset data with no coverage hole and 100 m coverage hole dataset respectively.

Dataset with 100 m coverage hole shows a difference of ~3dB in amplitude with reference dataset. Similarly, SMA and dB converted SMA maps were generated for full offset, nears, near-mids, far-mids and far offset groups with coverage hole sizes ranging from 100 to 500 m with an increment of 100 m for shallow target.

The SMA process has filled-up the coverage hole to a little extent, however with very low amplitude. These amplitude differences gradually increased with increase in coverage hole size from 100 m to 500 m which is evident in figures (10 to 13).

Far offset group from 6 to 8 km have no major contribution for shallow target as the reflections are post critical (Figure 14).

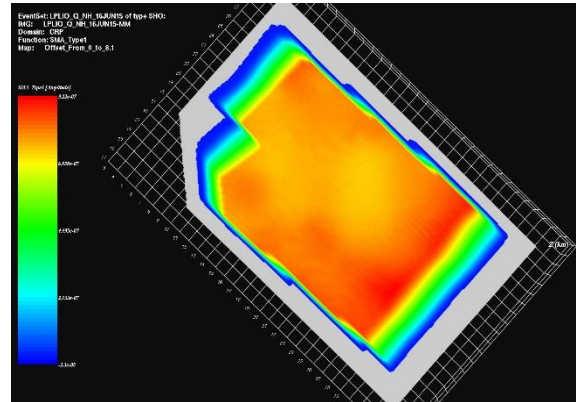


Figure 7: SMA Map for NO hole dataset, Offset- ALLS

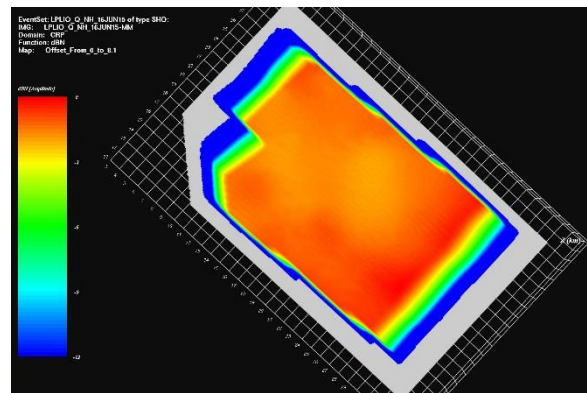


Figure 8: SMA_dB Map for NO hole dataset, Offset- ALLS

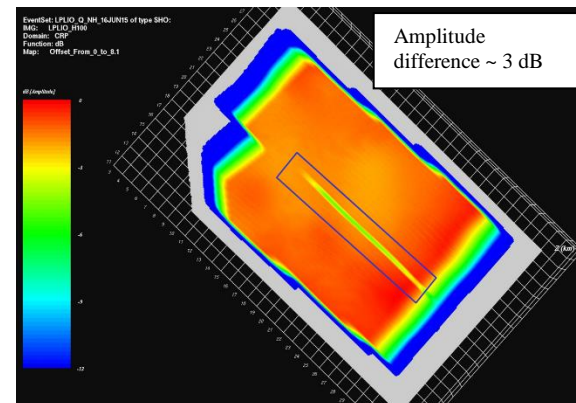


Figure 9: SMA_dB Map for 100m hole dataset, Offset- ALLS

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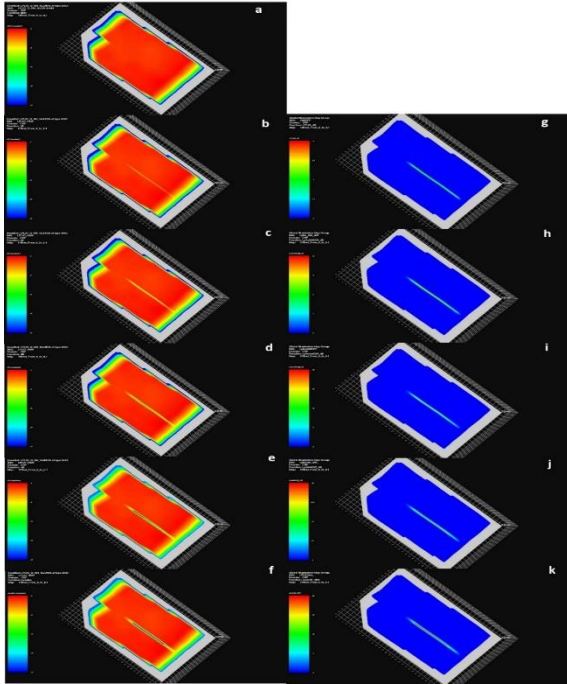


Figure 10: Offset-ALLS; SMA-dB Maps (left) and Difference Maps (right); (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

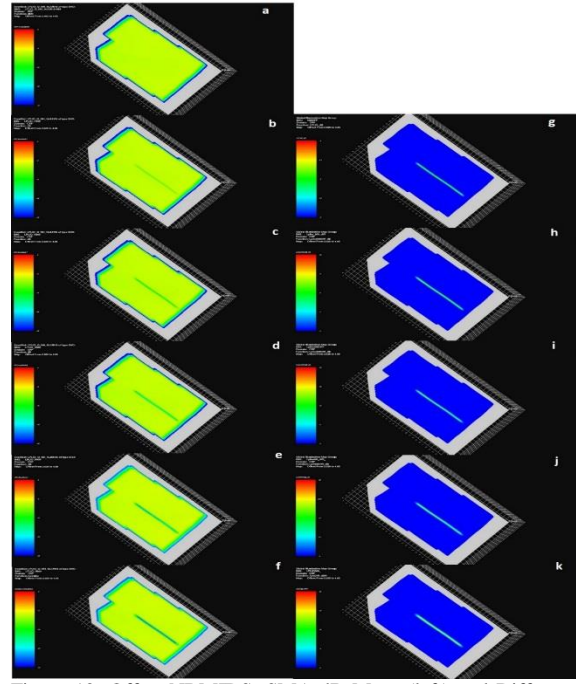


Figure 12: Offset-NRMIDS; SMA-dB Maps (left) and Difference Maps (right); (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

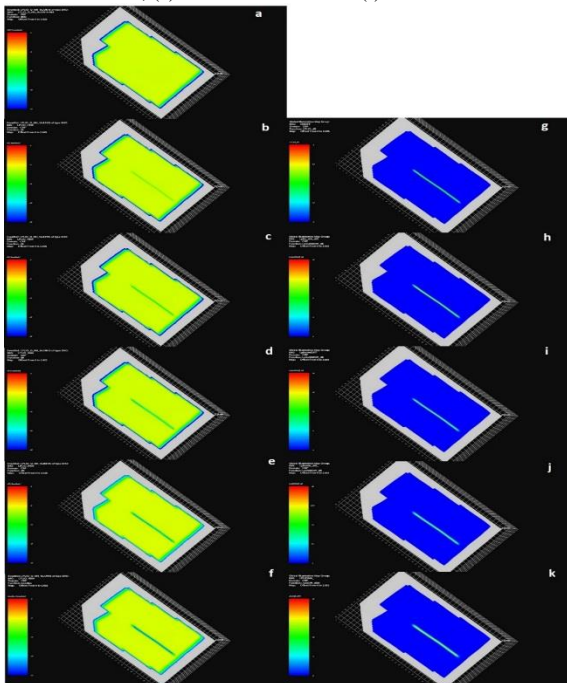


Figure 11: Offset-NEARS; SMA-dB Maps (left) and Difference Maps (right); (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

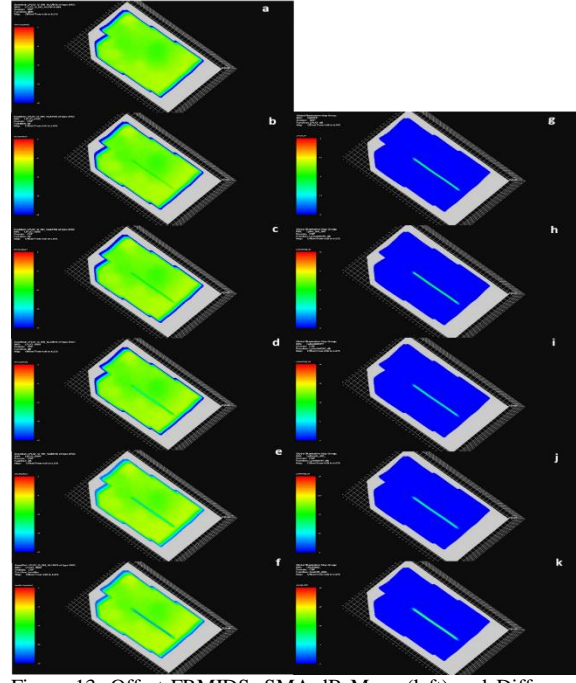


Figure 13: Offset-FRMIDS; SMA-dB Maps (left) and Difference Maps (right); (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

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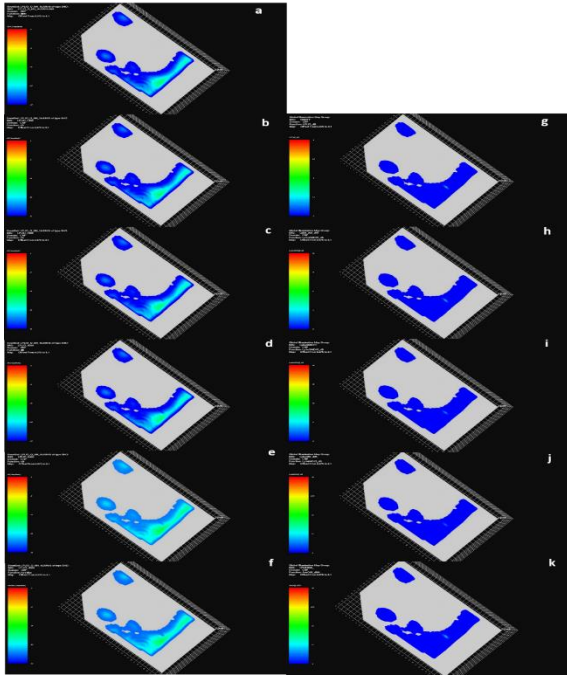


Figure 14: Offset-FARS; SMA-dB Maps (left) and Difference Maps (right); (a) No Hole, (b) Hole Size 100m, (c) Hole Size 200m, (d) Hole Size 300m, (e) Hole Size 400m and (f) Hole Size 500m

After analyzing the dB converted SMA maps offsetwise, a table was generated for amplitude difference for shallow target. It is evident from the Table1, that coverage hole size with 100m cannot be ignored for any offset group.

Target 1	Hole-size (m)	Alls	Nears	Near-Mids	Far-Mids
	100	3.3	3.3	3.1	2.6
	200	7.7	8.6	7.1	5.6
	300	19.7	23	16.8	11.6
	400	23	24.6	23.4	16.9
	500	32	27.8	29.4	31.5

Table 1: SMA_dB difference values (dB) for shallow target

For nears and near-mids, amplitude variation is very significant for 100 m coverage holes and hence no relaxation is permitted. However, coverage relaxation

less than 100 m on far-mids for shallow targets can be considered. Fars contribution was null and void as it has no reflections. Thus, infill requirement becomes very critical for shallow targets.

Target 2	Hole-size (m)	Alls	Nears	Near-Mids	Far-Mids	Fars
	100	1.8	1.8	1.7	1.6	1.5
	200	4.2	4.6	4.5	4.4	4.2
	300	7	7.5	7.4	7	6.5
	400	9	9	8.8	7.8	7.8
	500	11	14	13.5	13	12.5
	600	14	13.5	14	14.5	15
	700	18	14	13.5	14.2	15

Table 2: SMA_dB difference values (dB) for deep target

Similarly, a table was generated for deeper target. Amplitude differences gradually increased as the coverage hole size increases from 100 m to 700 m. It is evident from the Table2, that the coverage holes can be relaxed upto 100 m for all the offsets. Even consideration can be given for less than 200 m coverage hole size on far-mids and fars for deeper targets. Hence, infill specifications can be further relaxed for deeper targets.

Conclusions

In pre-survey design stage, infill assessment based on acceptability of coverage gaps is efficiently carried out through SMA modelling. These coverage specifications can be effectively derived by integrating modelling outcomes with geophysical criteria. This is considered as a realistic and conservative approach as it does not include data interpolation schemes while generating the results.

The results shows that infill requirements are very critical for near to near mid offset groups for shallow targets. This can be further relaxed at far and far mids below 100 m infill specifications. For deeper targets, infill specifications can be relaxed upto 100 m for all

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offset groups and this can be further relaxed to less than 200 m at far and far mid offset groups. These coverage specifications are specific to a survey area.

The benefits of this approach will be of two fold. Primarily, reduction of the coverage overlaps at nears and near mids while shooting prime lines. Secondly, to shoot only identified coverage gaps while shooting infills. Thus, it will lead to optimization of infill volume and hence will reduce the survey cost, turnaround time and HSE exposures at sea.

This outcome also advocates the importance of advanced streamer configuration having variable streamer separations from nears to fars.

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Acknowledgements

The authors would like to extend sincere gratitude to the asset team for providing modeling inputs. The authors also would like to thank Ram Kripal and Pramod Srivastava for critical review of this work. The authors are grateful to Head of Exploration for assigning this project, and extending support and encouragement throughout the project. Additionally, we thank Reliance Industries Ltd for granting permission to publish this work.

